The Engineer

AUGUST 7, 1953 — 28, ESSEX ST., STRAND, LONDON, W.C.2. — TWO SHILLINGS

UNIVERSITY OF MICHIGAN
AUG 24 1953
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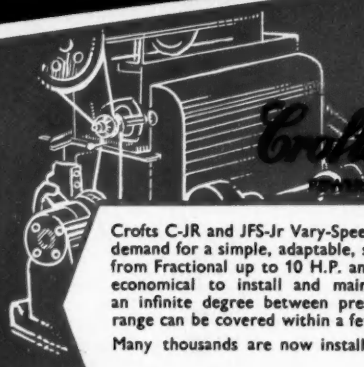
STOCK

Crofts . . . . HAVE THE ANSWERS TO YOUR VARIABLE SPEED PROBLEMS



Crofts "C-JR" VARY-SPEED CONTROLS

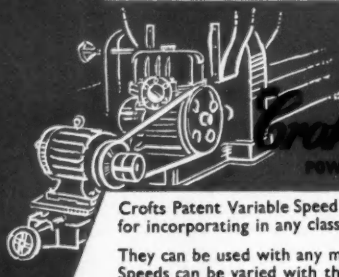
POWERS FROM FRACTIONAL UP TO 10 H.P. RATIOS UP TO 8 TO 1

PUBLICATION 252/10

Crofts C-JR and JFS-Jr Vary-Speed Units are the most satisfactory solution to meet industry's demand for a simple, adaptable, small power speed control. Suitable for transmitting powers from Fractional up to 10 H.P. and for speed variations up to 8 to 1, these low cost Units—economical to install and maintain—enable machinery speeds to be varied at will, to an infinite degree between preselected minimum and maximum speeds. The entire speed range can be covered within a few seconds.

Many thousands are now installed and giving satisfactory service in a variety of industries.

IMMEDIATE DELIVERY



Crofts VARIABLE SPEED PULLEYS

POWERS FROM FRACTIONAL UP TO 50 H.P. RATIOS UP TO 15 TO 1

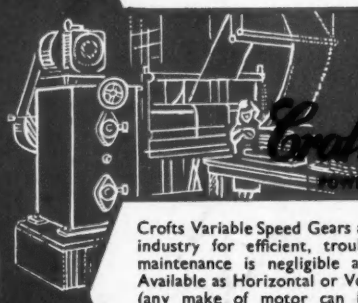
PUBLICATION 5225/10

Crofts Patent Variable Speed Pulley Drives are simple, economical and efficient devices, suitable for incorporating in any class of machine or in any type of drive.

They can be used with any make and type of standard electric motor and are easily installed. Speeds can be varied with the machine running by the simple method of Handwheel or Push Button Control . . . speed change is smooth, silent and infinitely progressive upwards or downwards.

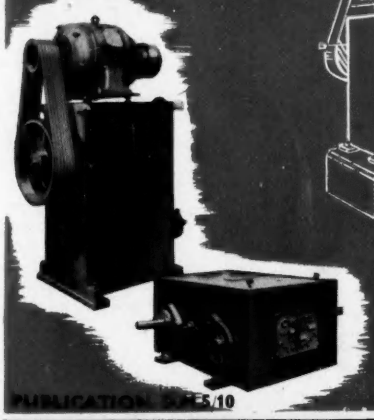
Thousands have been economically applied to all classes of machinery.

STOCKED IN A WIDE RANGE OF SIZES.



Crofts VARIABLE SPEED GEARS

POWERS FROM FRACTIONAL UP TO 150 H.P. RATIOS UP TO 14 TO 1



PUBLICATION 5225/10

Crofts Variable Speed Gears are compact, strong, totally enclosed Units well-known throughout industry for efficient, trouble-free performance. Because of their simple construction, maintenance is negligible and can be carried out *immediately* by any maintenance man. Available as Horizontal or Vertical types, they can be supplied with or without motor mounting (any make of motor can be fitted) providing a completely self-contained power unit. They can be mounted in any convenient position with any method of control, local or remote, fitted to suit the operator.

MANY SIZES FOR IMMEDIATE DELIVERY.

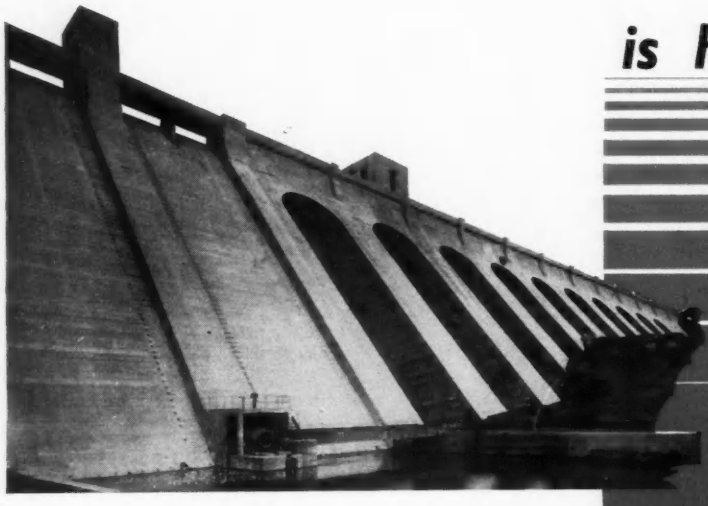
Crofts THE BEST KNOWN NAME IN MECHANICAL POWER TRANSMISSION . . .

CROFTS (ENGINEERS) LTD., BRADFORD

TELEPHONE . . . TELEGRAMS . . . CROFTERS BRADFORD

GLENFIELD

EQUIPMENT



An impounding reservoir anywhere

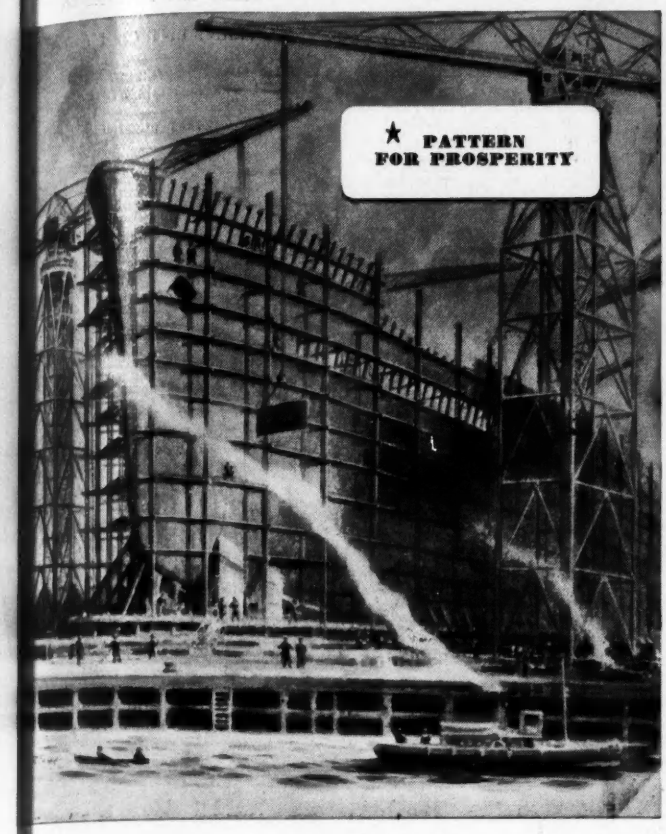
is here

Needle Valves with Jet Dispersers for scour and compensation water.

Glenfield

GLENFIELD & KENNEDY, LIMITED KILMARNOCK

Head Office and Works: KILMARNOCK, SCOTLAND.



★

More than half the World's total of new shipping is now being built in British yards and the industry is on the threshold of a prosperity unknown in the peaceful years. This is the reward of technical progress and high productivity, for the industry has been quick to see the need for adapting yards to newer methods of construction, large-scale prefabrication, and the employment of modern metal-working techniques. This is why Wimet carbide tools are being increasingly used for a multitude of metal-working applications in this great industry.

Wimet

WICKMAN *of* COVENTRY

270 ST

THE ENGINEER

ESTABLISHED 1856

Vol. 196 No. 5089

AUGUST 7, 1953

28, Essex Street, Strand, London, W.C.2

Telephone : CENtral 6565 Telegrams : Engineer Newspaper, Estrand, London

Published every Friday Registered as a Newspaper

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NOTICE TO READERS

All letters intended for insertion in 'The Engineer' or containing questions should be accompanied by the name and address of the writer, not necessarily for publication, but as a proof of good faith. No notice whatever can be taken of anonymous communications. No undertaking can be given to return drawings or manuscripts; correspondents are therefore requested to keep copies.

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WORDING OF ADVERTISEMENTS: Approximately the first 25 letters of each advertisement are set in heavy type. Advertisers are therefore advised to begin their advertisements with the words they want emphasized.

Advertisements received by Mid-day Tuesday will appear in the issue of Friday the same week. Orders must be accompanied by a remittance.

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PUBLIC APPOINTMENTS

WOOLWICH POLYTECHNIC
LONDON, S.E.18

Principal: J. S. TAIT, Ph.D., B.Sc., A.R.T.C., M.I.E.E., A.M.I.Mech.E.

CIVIL AND MECHANICAL ENGINEERING DEPARTMENT

SENIOR LECTURER

Applications invited for a SENIOR LECTURER in the Civil and Mechanical Engineering Department (with knowledge of structural theory and design (civil engineering structures)), and preferably also surveying, from candidates with a good Honours Degree and practical experience in the design of civil engineering structures.

Salary scale: £1040–£25–£1190, plus London allowance.

Applications invited for ASSISTANT, Grade A, for machine shop engineering and motor vehicle work, from candidates with an Engineering Degree, Higher National Certificate or similar qualification.

Salary, Burnham Further Education Scale, between £511 and £832, according to qualifications and experience.

Particulars and application form from Clerk to Governors, to be returned by 29th August, 1953.

E9261

UNIVERSITY OF PESHAWAR
(WEST PAKISTAN)

PROFESSORS OF ELECTRICAL AND MECHANICAL ENGINEERS

Applications are invited for (i) PROFESSOR OF ELECTRICAL ENGINEERING, and (ii) PROFESSOR OF MECHANICAL ENGINEERING in the University of Peshawar (West Pakistan).

Qualifications: (i) Honours Degree, (ii) experience of teaching Engineering Degree classes.

Salary £1500–£2000 per annum, according to qualifications, payable in Pakistan currency.

Terms of contract may be arranged by mutual agreement.

Application forms are obtainable on request from the High Commissioner for Pakistan, 35, Lowndes Square, London, S.W.1, and should reach Dr. M. R. Siddiqi, Vice-Chancellor, University of Peshawar, c/o The Educational Attache, Pakistan High Commission, 39, Lowndes Square, by 25th August, 1953.

E9754

DORSET COUNTY EDUCATION COMMITTEE

SOUTH DORSET TECHNICAL COLLEGE

ASSISTANT

Applications are invited for the full-time post of ASSISTANT to teach electrical engineering and allied subjects in courses leading to the Ordinary and Higher National Certificates and City and Guilds of London Examinations.

Salary according to Burnham Technical Scale, Grade B.

Application forms, which should be returned within two weeks of the appearance of this advertisement, may be obtained from the Principal, South Dorset Technical College, Newstead Road, Weymouth. (S.A.E.) E9750

THE UNIVERSITY OF SHEFFIELD

LECTURER IN MECHANICAL ENGINEERING

Applications are invited for an appointment as LECTURER IN MECHANICAL ENGINEERING. Facilities will be provided for research. The salary scale for Lecturers is £550 by £50 to £1100, together with F.S.S.U. provision and family allowance, initial salary depending on qualifications and experience.

Applications (four copies), including the names and addresses of three referees and, if desired, copies of testimonials, should reach the undersigned (from whom further particulars may be obtained) by 14th September, 1953.

A. W. CHAPMAN,
Registrar.

E9717

UNIVERSITY OF ABERDEEN

LECTURESHIP IN ENGINEERING

Applications are invited for a LECTURESHIP IN ENGINEERING. Salary, £550, rising by £50 to £800, placing according to qualifications and experience, with F.S.S.U. and children's allowances. Part of furniture removal expenses to Aberdeen refunded. Conditions of appointment and forms of application should be obtained from the undersigned, with whom applications (6 copies) should be lodged by 5th September, 1953. Applicants outside the British Isles may submit one copy of application.

W. S. ANGUS,
Secretary.

The University,
Aberdeen. E9719

UNIVERSITY OF NOTTINGHAM

LECTURER IN CIVIL ENGINEERING

Applications are invited for the above appointment. Applicants should have a good Honours Degree and at least two years' practical experience. Initial salary within the scale £550 by £50 to £1100, according to qualifications and experience.

Form of application and conditions of appointment may be obtained from the undersigned, to whom applications should be sent not later than Saturday, 29th August, 1953.

H. PICKBOURNE,
Registrar.

E9721

PUBLIC APPOINTMENTS

UNIVERSITY OF HONG KONG

WORKSHOP INSTRUCTOR

Applications are required for the post of WORKSHOP INSTRUCTOR. Salary, including allowances, for a married expatriate member of the staff, £1185 by £25 to £1285/£1405 by £25 to £1455/£1570 by £25 to £1620.

Applicants should have served a regular apprenticeship in a mechanical engineering workshop and should also hold a suitable qualification, such as a Higher National Certificate in Mechanical Engineering with Workshop Technology as one of the subjects, or a City and Guilds Certificate in Workshop Technology.

The University provides tourist-class sea passages and accommodates expatriate staff in Hong Kong at reasonable rentals.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 5, Gordon Square, London, W.C.1. Closing date for the receipt of applications is 1st September, 1953 E9724

THE UNIVERSITY OF LIVERPOOL

DEPARTMENT OF MECHANICAL ENGINEERING

LECTURER

Applications are invited for the post of LECTURER in Department of Mechanical Engineering.

The initial salary will be within the range of £550–£1100 per annum, according to qualifications and experience.

Applications, stating age, academic qualifications and experience, together with the names of three referees, should be received not later than 28th August, 1953, by the undersigned, from whom further particulars of the conditions of appointment may be obtained.

STANLEY DUMBELL,
Registrar.

July, 1953. E9657

COUNTY BOROUGH OF TYNEMOUTH

WATER DEPARTMENT

ENGINEERING ASSISTANTS—GRADES IV AND VI

Applications are invited for the above appointments from civil engineers with considerable experience in waterworks. The salaries will be in accordance with the National Salary Scales of :—

Grade IV, £555 to £600 per annum, and
Grade VI, £670 to £735 per annum.

Forms of application and conditions of appointment may be obtained from Mr. C. F. J. Lisle, B.Sc., A.M.I.C.E., M.I.W.E., Water Engineer and Manager, 8, Northumberland Square, North Shields, Northumberland, to whom they should be returned by Monday, the 24th August, 1953.

FRED. G. EGNER,
Town Clerk.

14, Northumberland Square,
North Shields,
27.7.53. E9701

BRITISH RAILWAYS

EASTERN REGION

ASSISTANT

ASSISTANT required for Railway Civil Engineer's Office in London. Applicants should be fully experienced in surveying and levelling and setting out work; have theoretical and practical knowledge of general schemes and estimates, structural design, contract documents, &c.; also experienced in detailing and designing reinforced concrete. Salary range £612 5s. to £687 15s. Five-day week and canteen facilities. Certain free and reduced rate rail travelling facilities after qualifying period of service.—Apply in writing, giving full particulars as to age, experience and qualifications possessed, to Civil Engineer, Eastern Region, King's Cross Station, London, N.1.

E9730

BRITISH RAILWAYS

EASTERN REGION

ASSISTANT

ASSISTANT required for Railway Civil Engineer's Office in London. Applicants should have had experience in large permanent way schemes layouts, taking off quantities, making of estimates and whole schemes, including ancillary works and buildings. Salary range £612 5s. to £687 15s. Five-day week and canteen facilities. Certain free and other reduced rate rail travelling facilities after qualifying period of service.—Apply in writing, giving full particulars as to age, experience and qualifications possessed, to Civil Engineer, Eastern Region, King's Cross Station, London, N.1. E9729

LONDON COUNTY COUNCIL

MECHANICAL ENGINEER

MECHANICAL ENGINEER required, good general experience, capable draughtsman, to make surveys, prepare schemes and specifications for erection of large boiler plants, heating and ventilation, chlorination and filtration. Grad. I.Mech.E. or equivalent an advantage. Salary up to £696 according to quals. and expce.—Application form from Chief Engineer (53/30), London County Council, County Hall, S.E.1, returnable within next fourteen days. (Enclose S.A.E.) (818) E9727

PUBLIC APPOINTMENTS

BOROUGH OF NELSON

WATERWORKS DEPARTMENT

ENGINEERING ASSISTANTS

Applications are invited for the following appointments in the office of the Waterworks Engineer and Manager :—

(a) SENIOR CIVIL ENGINEERING ASSISTANT. Salary in accordance with A.P.T. Division, Grade V, of the National Scales of Salaries (£595–£645 per annum).

(b) JUNIOR CIVIL ENGINEERING ASSISTANT. Salary in accordance with A.P.T. Division, Grade III, of the National Scales of Salaries (£525–£570 per annum).

The appointments will be subject to termination by one month's notice on either side, the provisions of the Local Government Superannuation Act, 1937, and the successful candidates passing medical examinations.

Applicants for the post of Senior Civil Engineering Assistant should have general waterworks experience, preferably including borehole pumping machinery and reinforced concrete work, and should have passed Sections A and B of the examination of the Institution of Civil Engineers (or hold equivalent qualification).

The waterworks undertaking has some interesting work on hand and both appointments offer an opportunity to obtain useful experience in the profession.

Applications (suitably endorsed), stating age, qualifications and giving details of experience, together with copies of two recent testimonials or the names and addresses of two persons to whom reference may be made, should be delivered to the undersigned not later than Monday, the 24th August, 1953.

F. W. ROBERTS,
Town Clerk.

Town Hall,
Nelson,
30th July, 1953. E9772

HER MAJESTY'S COLONIAL SERVICE

PUBLIC WORKS DEPARTMENT, HONG KONG

ENGINEERS

Applications are invited for the following posts :—ENGINEERS, Public Works Department, Hong Kong.

Appointment is on contract-gratuity terms with salary in the scale 1050 dollars to 1875 dollars per mensem (i.e. £787–£1406 p.a.). Starting salary determined by age, experience and war service. Substantial gratuity payable on satisfactory completion of contract.

Expatriation allowance varying from 280 dollars to 373 dollars per mensem (£210–£279 p.a.), according to salary, together with a temporary, variable, high-cost-of-living allowance, also payable. (Rate of exchange 16 dollars equals £1).

Candidates, preferably under 40 years of age, must hold a recognised University Degree or Diploma in Civil Engineering carrying exemption from Sections I and II of the A.M.I.C.E. examinations, plus two years' approved practical experience or be A.M.I.C.E.

Duties would include the design and supervision of construction of reinforced concrete structures in particular (including piers and ancillary works in connection with cross harbour ferry service) and engineering projects in general.

Full details on application.

Apply in writing to the Director of Recruitment, Colonial Office, Great Smith Street, London, S.W.1, giving briefly age, qualifications and experience. Mention the reference number CDE 112/51/01.

E9757

THE BRITISH IRON AND STEEL RESEARCH ASSOCIATION

SHEFFIELD LABORATORIES

APPLIED PHYSICISTS AND RESEARCH ENGINEERS

Applications are invited from APPLIED PHYSICISTS and RESEARCH ENGINEERS for senior and junior posts in the Sheffield Laboratories of the above Association, for research in industrial metal working processes, such as rolling and forging. Work will include research in new laboratories uniquely equipped with metal working machinery, and participation in works investigations throughout the country. Candidates for senior posts should have an Honours Degree and two to three years' research experience, and for junior appointments a Degree or equivalent qualification. Age range 23–30. Starting salary according to age, qualifications and experience. Posts are superannuated under the F.S.S.U.—Written applications only, quoting "Metal Working," to Personnel Officer, B.I.S.R.A., 11, Park Lane, London, W.1. E9732

DORCHESTER RURAL DISTRICT COUNCIL

WATER AND SEWAGE DISPOSAL WORKS

APPOINTMENT OF FITTER-MECHANIC

Applications are invited for the above appointment at a salary in accordance with Grade V of the Miscellaneous Division of the National Scale of Salaries (£480, rising to £540), plus travelling expenses.

Housing accommodation is available.

Details of duties and application forms obtainable from the undersigned, to whom applications should be sent by not later than first post on Monday, the 24th August, 1953.

A. E. SYMES,
Clerk of the Council.

Council Offices,
58, High West Street,
Dorchester,
4th August, 1953. E9768

PUBLIC APPOINTMENTS

GOVERNMENT OF MALTA

JESUITS HILL POWER STATION AND DISTRIBUTION SYSTEM

RESIDENT ENGINEER

Applications are invited for the temporary post of RESIDENT ENGINEER for the Malta Electricity Supply Scheme. The initial installation consists of 3 × 5000kW turbo-alternators, with 3 × 70,000lb./hr. oil-fired boilers and ancillary equipment. The distribution system consists of an 11kV. ring main system with underground cables, overhead lines, and indoor and outdoor substations, and low-voltage distribution, and the adaption of the existing single-phase lines into the new system.

Candidates should be Corporate Members of one of the Senior Engineering Institutions or possess equivalent qualifications, and have had sound training in electrical and mechanical engineering with subsequent practical experience in the installation and operation of steam turbine generating plant, water-tube boilers, and ancillary plant, and 11kV. and L.V. cables, overhead lines and substation equipment.

The appointment is temporary for a period of two years with the option of extension by one year on an inclusive salary of £2000 per annum. Free passages are provided at the commencement and completion of the contract. Vacation leave at the rate of two and half days per completed month of residential service.

Applications, endorsed "Residential Engineer, Malta," stating age, qualifications and experience, should be forwarded immediately to the undersigned who will communicate with candidates selected for further consideration.

PREECE, CARDEW AND RIDER,
8 and 10, Queen Anne's Gate,
London, S.W.1. E9775

HER MAJESTY'S COLONIAL SERVICE

PUBLIC WORKS DEPARTMENT, BRITISH GUIANA

RESIDENT ENGINEER

Applications are invited for the following post :—RESIDENT ENGINEER, Public Works Department, British Guiana.

Appointment is on agreement for three years in the first instance with fixed salary of £1100 p.a., plus cost-of-living allowance. Duties include the supervision of large-scale drainage and irrigation works and candidates should have had at least five years' experience on works involving mechanical equipment, draglines, &c. Qualifications: University Degree or Diploma in Civil Engineering carrying exemption from Sections I and II of the A.M.I.C.E. or be Corporate Members of the Institution of Civil Engineers. Application should be made not later than 31st August.

Apply in writing to the Director of Recruitment, Colonial Office, Great Smith Street, London, S.W.1, giving briefly age, qualifications and experience. Mention the reference number CDE 112/30/02.

E9758

WARWICKSHIRE COUNTY COUNCIL

TO HEATING AND ELECTRICAL ENGINEERS

Firms desirous of having their names placed upon a LIST OF APPROVED CONTRACTORS from whom the Warwickshire County Council will invite Tenders for schemes costing £1250 and over for (a) Heating, Hot and Cold Water Supplies, Steam Services, Laundry and Kitchen Equipment; and (b) Electric Light and Power Installations, should make application on or before Monday, 31st August, 1953, to G. R. Barnsley, F.R.I.B.A., County Architect, Shire Hall, Warwick.

Applicants must forward particulars of contracts recently executed by them, giving the names and addresses of local authorities or persons to whom reference can be made. Tenders will be considered only from firms included in the official list, which will be compiled by the appropriate Committee after consideration of applications.

Contractors whose names are already included in the Council's approved list need not make application as their names will automatically be transferred to the new list.

L. EDGAR STEPHENS,
Clerk of the Council.

Shire Hall, Warwick,
July, 1953. E9715

CITY OF BIRMINGHAM

WATER DEPARTMENT

ASSISTANT ENGINEER, NEW WORKS AND CONTRACTS

Applications are invited for the above appointment. Salary scale A.P.T. I–IV (£465–£600) per annum. Post pensionable, medical examination.

The successful candidate, who must possess a University Degree in Civil Engineering or have passed or obtained exemption from Parts I and II of the Final Examination of the Institution of Civil Engineers, will be required to assist with the design, preparation of drawings, &c., and administration of construction both by direct labour and contract, of general civil engineering projects, including trunk mains extensions, waterworks treatment plant and service reservoirs. Previous experience not necessary but preference given to neat and tidy draughtsmen.

Applications on forms obtainable from the General Manager and Secretary, City of Birmingham Water Department, Council House, Edmund Street, Birmingham, 3, must be returned not later than 22nd August, 1953. Canvassing disqualifies.

August, 1953. E9767

THE ENGINEER

AUGUST 7, 1953

Scheduled Air Route Development

THE consideration of applications from air transport undertakings to operate certain classes of scheduled air services forms the main subject of a recent report of the Air Transport Advisory Council. These applications arose out of the Government's air transport policy which became effective in July, 1952, with the issue to the Council of new terms of reference. This policy was reported in our issue of August 8, 1952, page 177, and permission to operate new routes both by B.E.A., B.O.A.C. and independent companies has been noted in these columns in recent months. In a foreword to this report the Minister of Civil Aviation stated that he had already accepted 132 out of 140 of the Council's recommendations. He endorsed also the Council's conclusion that this new development was being achieved without undermining the route networks of the two airways corporations, which, he stated, were maintaining and strengthening their position. He referred also to the fact that the general public, who are entitled to make representations to the Council on the adequacy of air transport facilities, had made only one such representation. It had to do with the North Atlantic route facilities and included a request for a shopping service in London for residents in North America. The report notes that by March 31st this year the number of applications received amounted to 184, 166 of them coming from independent air transport companies. Sixty-three of the applications were for normal scheduled services, fifty-seven for internal services, twenty-five Colonial coach services, thirteen for inclusive tour services, twenty-one for all-freight services, and five for vehicle ferry services. Thirty-seven of the 140 applications so far considered were recommended for rejection. The report contains seven appendices, of which the last lists the recommendations of the Council up to March 31, 1953.

"The Model Engineer" Exhibition

WHEN "The Model Engineer" Exhibition opens at the New Horticultural Hall, Westminster, on Wednesday, August 19th, several hundreds of the best engineering models built in this country will be displayed by amateur craftsmen from all walks of life. Advance information received from the organisers indicates that both in the competition sections and in the demonstrations of working models, there will be some outstanding exhibits which will show once again that the originality and ingenuity of the model maker continues unabated in an ever widening field. The competition models will include many kinds of engines from the earliest to those of more recent design and the usual large numbers of aircraft, ship and rolling stock models. One working model which will attract much attention will be that of a showman's roundabout complete in detail with galloping horses and typical music, and measuring some 6ft 8in in diameter. Although there is now available a good selection of equipment specially made for amateur craftsmen many model makers design and make such equipment as part of their hobby, and a number of examples of the machine tools and accessories made by these specialists in miniature work will be shown. Amongst the railway models will be a new miniature of the Talyllyn Railway, described as the oldest surviving narrow gauge steam hauled passenger carrying railway in the world. The water tank built for demonstrating marine models will again occupy a prominent position and will be used to show the working of radio controlled models and other vessels. The motor-car models will include a number of the now very popular miniature racing cars, some of which will be shown racing on a specially constructed track.

British Association Meeting in September

THE 115th annual meeting of the British Association is to be held this year from September 2nd to September 9th in Liverpool. The Association points out that these annual meetings are the largest general gatherings of scientists in the country, their objects being to let scientists meet each other and discuss their work against the background of science as a whole, to inform the public on the progress of science and to increase public understanding of the methods and objects of science; the interpretation of science to the public continues to be one of the main functions of the Association. This year the President is Sir Edward V. Appleton, who will deliver an address entitled "Science for its Own Sake," during the course of the meeting. The programme of the meeting has just been published; it contains the usual very wide variety of topics, classified according to the Association's thirteen sections. In the engineering section, Section G, the presidential address, "Engineering in the Next Two Thousand Years," will be given by Lord Dudley Gordon. Papers on many engineering subjects will be presented, including computing machines, solar and nuclear power, electronic methods in telephone switching, colour television and district heating. One paper is about the isodynamometer (a direct method of model analysis of plane portal structures) and there are papers on the design of creep resisting steels; the uses of titanium, combined magnetisation of magnetic materials, calorimetry with particular reference to magnetic steels, and electro-mechanical analogies. The programme of excursions includes visits to many places of engineering interest in the Liverpool area.

The Port of London

THE annual report of the London General Shipowners' Society for the year 1952–53 refers to the work of the London Port Users' Committee which was established in 1952 and comprises shipowners and merchants using the Port of London. During the year teams from the committee visited all dock areas and studied in detail the problems peculiar to each. The report points out that to a great extent the efficiency of the port depends upon the relationship between the shipowners' and/or stevedores' staff and the local representatives of the port authority and H.M. Customs. The rehabilitation of the port has been much delayed after the war, largely owing to labour difficulties and the lack of the necessary materials. It is stated in the report that now, under pressure from the various committees and the port operation panel, the necessary steel is forthcoming and work is going ahead satisfactorily. The P.L.A. has a large building programme which embraces not only the rehabilitation of the old deep-water berths, but also the construction of new ones. The whole programme is obviously a long-term one, but it is hoped steady progress will be made. In dealing with the subject of mechanisation the report says that the degree of mechanisation desirable varies with trades. Progress in introducing mechanical handling has been slow but as and when adequate manning scales can be agreed, mechanisation, the report contends, will undoubtedly be introduced on an increasing scale.

An Oil Refinery in India

THERE is at present under construction on Trombay Island, Bombay, an oil refinery with a designed capacity of 2,000,000 tons a year, which, when completed in 1955, will be the largest refinery in India. This plant will process crude oil from the Middle East and its output will supply a considerable proportion of India's requirements of petroleum products, including petrol, kerosene, diesel oils, furnace fuels, and bitumen. The refinery will cost nearly £20,000,000 and the project is being carried out by a new company, Burmah-Shell Refineries, Ltd., which is owned jointly by the Shell Petroleum Company, Ltd., and the Burmah Oil Company, Ltd. As the existing loading and unloading facilities on Trombay Island will be inadequate for the combined use of the various oil companies, the Bombay Port Trust is to build a new marine terminal at Butcher Island, some 3 miles away. The two islands will be connected by submarine pipelines, through which the crude oil for the new refinery will be pumped from Butcher Island. Some of the refined products will be pumped back through pipelines from Trombay Island to Butcher Island for loading into tankers for distribution to other parts of India. Some of the refined products will also be piped directly to the distributing company's installations in the Bombay area, whilst the remainder will be transported by road and rail to bulk depots. The main refining operations at the plant will include crude distillation, vacuum distillation, catalytic cracking, gas separation, product treating, bitumen manufacture, and packing.

Rural Water Supplies

IN the course of replying to a question with regard to rural water supplies in the House of Commons last week, the Parliamentary Secretary to the Ministry of Housing and Local Government, Mr. Ernest Marples, said that on the whole this country was well off for piped water supplies. Some 95 per cent of the population had piped water supplies in their houses and others had a stand-pipe near at hand. In rural areas the percentage without a piped water supply was not more than 18 or 20, and only one-fifth of the population of England and Wales lived in areas under the jurisdiction of rural district councils. He then went on to point out to the House that one-third of the water supply work authorised during the past year or so had been for rural districts. During the year 1951/52, £18,000,000 worth of water supply work was authorised and of that £6,000,000 worth was in rural districts. Of the total of £21,000,000 authorised in 1952–53, £7,000,000 worth was for rural districts. During this year and next year it was intended to authorise an extra £500,000 of water supply work over and above the capital investment programme originally contemplated. This extra work would be devoted entirely to schemes where agricultural interests predominated and where water was wanted by farms or was particularly urgent. Mr. Marples went on to point out that the most severe limitations had been imposed upon water supply works in past years by the lack of suitable materials, particularly cast iron pipes. The production of these pipes had increased and during the first five months of this year the deliveries had been 12 per cent greater than in the corresponding period of 1952.

Paint Coating Thickness Meters

By R. QUARENDON, Ph.D., B.Sc., D.I.C., A.R.C.S.

No. II—(*Concluded from page* 133, *July* 31*st*)

Various commercial and other meters which during recent years have been made available for the measurement of the thickness of paint coatings are described. The various meters described include those for the measurement of coatings on magnetic and non-magnetic bases, and on conducting and non-conducting bases. One or two meters have been designed for wet films. The instruments described are of British or American manufacture. The design, method of use and limitations of the meters are described, with some remarks on methods of calibration and accuracy.

Magnetic Attraction Gauges

A CLASS of coating thickness meter which includes one of the oldest as well as the simplest available meters is the magnetic attraction gauge. The use of this kind of gauge depends on the effect of the paint film on the force of attraction of the magnetic base for a suitably designed magnet. Some magnetic attraction gauges use a permanent magnet, while others are designed with the measuring head in the form of a solenoid.

The Brenner " Magne-Gage " (Fig. 5) is one of the oldest coating thickness meters in industrial use, and has found widespread acceptance in the United States since its introduction about fifteen years ago. It was developed by Abner Brenner, of the National Bureau of Standards, and is marketed by the American Instrument Company of Maryland, Washington, D.C. It is essentially a laboratory instrument and its usefulness is somewhat limited by the design, which makes it necessary to bring the test piece to the meter, and to place it vertically below the test head. It is therefore not possible to make a survey of a large structure such as a motor-car body.

In the Brenner " Magne-Gage," a small cylindrical permanent bar magnet is suspended freely from a pivoted arm, and is brought into contact with the surface of

Fig. 5—The Brenner " Magne-Gage "

the paint film by turning a dial located at the fulcrum of the arm. A pull is then applied to the magnet via the spring-loaded dial to overcome the force of attraction between the magnet and the base ; this force is a measure of the thickness of the film, and is read from the scale of the dial, which is calibrated in terms of film thickness. The assembly used for this purpose is a modification of the Sanford magnetic balance devised for measuring the magnetic permeability of austenitic steel.

Four interchangeable magnets are provided with the " Magne-Gage," to cover the four thickness ranges 0–2 mils, 2–7 mils, 7–25 mils and 25–80 mils. The gauge may be used on flat test pieces not less than $\frac{3}{4}$in square, on spheres not less than $\frac{3}{4}$in diameter, and on cylinders not less than $\frac{1}{4}$in diameter.

The A.R.D. coating thickness meter made by Griffin and Tatlock, Ltd., and illustrated in Fig. 6, was introduced at the 1950 exhibition of the Physical Society. Very similar in operation to the Brenner " Magne-Gage," the A.R.D. thickness meter

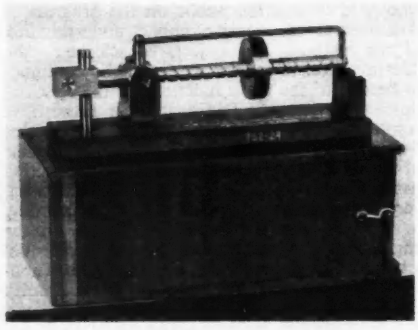

Fig. 6—" A.R.D. " Coating Thickness Tester

uses the principle of the steelyard instead of the Sanford balance for the measurement of the pull of the magnet. A pivoted beam has at one end the magnet, and at the other the balance weight moving along a helical track provided with a graduated scale. Interchangeable weights enable coatings with different ranges of thickness to be tested. The thickness of the coating is derived from calibration curves prepared with the aid of standard specimens of electro-deposited chromium platings of known thickness on mild steel.

One of the simplest and cheapest examples of the magnetic attraction gauge is the B.S.A. - Tinsley pencil gauge (Fig. 7), manufactured by Tinsley Industrial Instruments, Ltd., and originally developed by the B.S.A. Group Research Centre. This gauge is designed in pencil form for convenience in carrying around in the pocket. Although it cannot be expected to give such a high accuracy as some of the more elaborate meters, it is very useful where it is desired to make a rapid survey at a number of points over a large area.

This gauge has a special light spring-loaded magnet in a pencil-like tube forming the body of the gage. To measure the film thickness, the magnet is placed on the test surface, and the body of the gauge is withdrawn, thus extending the spring. The extension of the spring when the force of attraction for the base metal is overcome is a measure of the thickness of the film, and is read from the scale engraved on the body of the gauge.

Measurements with this gauge are claimed to be made with a mean accuracy of plus or minus 15 per cent, and cover a thickness range of 0·02 mil to 10 mils.

Another variant of the magnetic attraction gauge is the Lipson gauge (Fig. 8), developed by S. Lipson, of the Frankford Arsenal of Philadelphia. In general principle it resembles the B.S.A.-Tinsley gauge, but uses an electromagnet with soft iron core instead of the permanent magnet ; this consists of a solenoid about 4in long by 2in diameter. Instead of using tension in the spring for detaching the magnet from the paint film, the method employed is to place the iron core of the solenoid in contact with the surface, and to raise the coil of the solenoid until the electromagnetic force is increased enough for contact to be broken. The position of the iron core relative to the coil is used to determine the film thickness, and is read from a scale on a glass tube enclosing an indicator rod attached to the upper end of the core rod. The scale is calibrated in mils.

The Lipson gauge is probably one of the simplest gauges capable of a fairly high order of accuracy. The reproducibility is claimed to be plus or minus 5 per cent for films up to 3 mils in thickness, and plus or minus 3 per cent for films up to 8 mils thick. The latter thickness is the maximum which can be measured. A disadvantage of this gauge is that it must be used with the coil in a vertical position. A warming period of twenty minutes must be allowed for the instrument to stabilise itself if temperature errors are to be avoided.

Penetrometers

Penetrometers are direct-reading gauges distinguished as a class from other kinds of gauges by the fact that they do not make use of some physical property, such as magnetic inductance or capacitance, and do not therefore require the use of calibration curves.

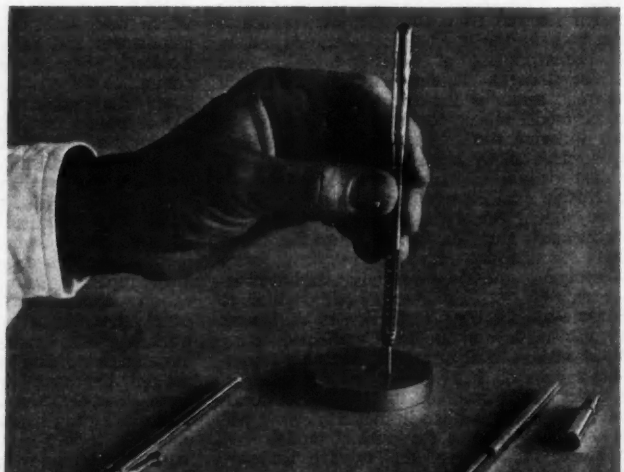

Fig. 7—" Pencil " Gauge

They are simple and rapid in operation and can be capable of a high degree of precision They have special importance for wet films since for this purpose no other kind of gauge is practicable.

Penetrometers generally employ a needle to pierce the paint film, and usually make use of an electrical current to indicate when the needle is in contact with the base material. This means that the latter must be an electrical conductor, and, of course, the surface coating must be non-conductive.

A well-conceived gauge of this type is the Gardner gauge (Fig. 9) ; this is an American meter, designed and developed by M. R. Euverard, of the Interchemical Corporation, and made by the Henry A. Gardner Inc., of Bethesda, Maryland, U.S.A. It is very simple in design and operation and is claimed to be highly sensitive and to give highly reproducible measurements. It is normally adjusted to cover the range nil to 20 mils,

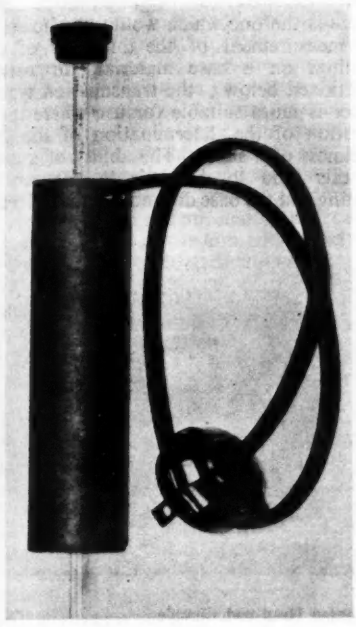

Fig. 8—Lipson Gauge

but by a simple readjustment it is possible to extend the range to 50 mils or even further if a longer contact needle is used.

The Gardner gauge attains high precision by a high degree of magnification. It employs a differential of the movement of the penetrometer needle and micrometer screw in conjunction with an engraved dial. One complete turn of the dial used to depress the needle corresponds to a needle travel of 2 mils, giving a magnification of 3000 on the scale. The scale is graduated in steps of 0·05 mils, and thickness of 0·01 mils may therefore be estimated.

The construction and use of the gauge may be understood by reference to the accompanying drawing. The zero position of the gauge must first be checked and set, if necessary ; to do this the gauge is placed on a clean flat electrically conducting surface, and the plug for the indicator lamp inserted through the socket at the bottom of the gauge.

The graduated dial is then turned in a clockwise direction until the lighting of the lamp shows that the needle has made contact with the metal surface. If necessary, the zero on the scale of the dial is then adjusted to coincide with the reference mark on the pillar at the side.

For the determination of the thickness of a film the gauge is then placed on the surface of the painted material and the dial is rotated to drive the needle through the film until the lamp shows that contact has again been made with the base.

For coatings ranging in thickness from 0·06 to 1·25 mils the reproducibility of individual readings is claimed to be $\pm 0{\cdot}03$ mil and the reproducibility of the zero setting $\pm 0{\cdot}02$ mil.

Of all gauges devised for the routine measurement of the thickness of paint coatings, the Interchemical wet film thickness gauge is the simplest and fastest. It may justly be described as a vest pocket gauge.

This gauge consists of a wheel with two raised concentric flanges, one on each side, rather like a small fishing reel. The bed between the flanges carries a raised circular rim, which is not concentric with the outer flanges, but has an offset centre and a diameter slightly less than the diameter of the outer flanges. The periphery of this inner rim is level with these flanges on one side of the wheel ; hence at the opposite end of the diameter there is a small clearance between the inner rim and the outer flange. The wheel turns on two bearings, one on each side of the gauge, and therefore rotates when the gauge is gripped between the finger and thumb of one hand and pushed over the surface of the paint film.

The scale of the gauge is engraved in mils of thickness on the outside round the periphery of the gauge. The zero mark is at the end of the diameter, where the clearance between the inner raised portion and the outer flange is nil, while the maximum on the scale is at the other end of this diameter where the clearance is greatest.

To use the gauge, it is placed on the paint film so that there is a clearance between the film and the inner rim, and the flanges rest on the underlying base material. It is then rolled over the surface towards the zero. This action brings the inner rim closer to the film until it makes contact with it and picks up some of the paint. The reading on the scale where this pick-up occurs represents the thickness of the film. The instrument is calibrated to make film thickness measurement when rotated in both directions, and in use the average of the readings is taken as the true thickness.

To cover the range of thicknesses normally encountered in practice several gauges with different scale ranges are provided. Seven gauges are made, with the following scale ranges and smallest graduations :—

Scale range, mils	Smallest graduation, mils
Nil to 0·4	0·02
Nil to 1	0·05
Nil to 2	0·1
Nil to 4	0·1
2 to 12	0·5
10 to 30	1·0
20 to 60	2·0

The fact that any one gauge covers such a limited range of thickness must be reckoned a disadvantage of the Interchemical gauge.

Reference should also be made here to the NJZ needle micrometer because it, too, is designed for the measurement of wet films, for which there is a distinct dearth of thickness meters. This is a somewhat elaborate instrument, involving the use of two microscopes. One of these microscopes is placed in a vertical position and has the penetrometer needle attached to the objective, while the other is placed at the side in a horizontal position.

The objective of the vertical microscope is first racked down until the tip of the needle touches the surface of the wet film ; this position may be recognised by observation through the horizontal microscope and by the fact that the wet paint tends to rise up the outside of the needle. The microscope is then further depressed until the needle makes contact with the metallic base, as shown by an electrical contact and the deflection of a galvanometer pointer in the circuit. The thickness of the film is obtained from the angular displacement of the fine adjustment of the microscope, obtained by preliminary calibration on a film of known thickness.

A widely used gauge, useful for measuring the covering power of a paint, the Pfund wet film gauge is in a sense a form of penetrometer. Instead of a needle, the gauge has a convex lens which is pressed down through the film until the lens makes contact with the base material. The diameter of the spot of paint adhering to the lens is measured by a microscope and the thickness of the coating t is calculated from the expression :—

$$t = d^2/16r$$

where d=diameter of the paint spot r=radius of curvature of the lens. The accuracy of the measurement is about 3 per cent, under favourable operating

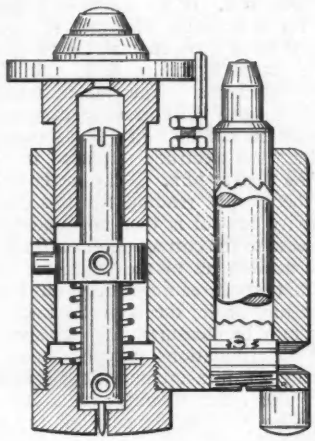

Fig. 9—Penetrometer Thickness Gauge

conditions. The chief sources of inaccuracy are roughness or splinters of wood surfaces and rust spots on metal. Coarse particles in imperfectly ground paint also cause difficulty.

In a recent article M. H. Switzer* has pointed out how the results obtained with the Pfund gauge may be applied to give the thickness of the finished film produced by the drying of the wet film on which the original measurements were made.

Electrical Capacitance Meters

Two recently introduced thickness meters make use of the measurement of the electrical capacitance of a coating to determine its thickness. These are the M.P.J. "Filmeter" manufactured by the M.P.J. Gage and Tool Company, Ltd., and the Fielden Proximity Meter, made by Fielden (Electronics), Ltd. Meters of this kind have high sensitivity. With modern electronic circuits it is possible to measure extremely small changes of capacitance with good accuracy and reproducibility. Since the sensitivity may be adjusted to suit the conditions, determinations may be made of very thin as well as thick coatings, with good accuracy.

The M.P.J. " Filmeter " has a light cylindrical exploring head connected by a length of flexible co-axial cable to the main body of the meter containing the control knobs, the indicating meter and the electronic valves and circuit. The head contains a built-in

* *Analytical Chemistry*, Vol. 23, pages 800–802, May, 1951.

standardising capacitor and terminates in a hardened, polished spherical electrode, which forms the test probe. To make a thickness determination, all that is necessary is to place the electrode in contact with the film, depress the switch and read the indication on the meter. The paint film acts as the dielectric of a condenser formed by the electrode, the film and the underlying metal base, whose capacitance varies with the thickness of the film and is determined by comparison with the capacitance of the standardising capacitor in the exploring head.

The meter is capable of measuring thickness ranging from a minimum of 0·2 mil to a maximum of about 30 mils, but the sensitivity required for the range 0·2 to 3 mil is different to that required for the range 2 to 30 mils. To make the appropriate adjustment of the sensitivity a "fix" on the scale is obtained by the use of a film of known thickness and the sensitivity control is adjusted until the pointer registers at the correct position on the scale.

Since the meter in effect measures the capacitance of the film, its calibration must be altered to suit the dielectric properties of the film under test. If, for example, it has been used for a cellulose film and it is desired to use it for a stove enamel, the new calibration is found by reference to two films of known thickness. The meter reading is first set to give the correct reading with the electrode in contact with the thinner film, and then the electrode is placed in contact with the thicker film. If the meter does not give the proper reading for this film, the sensitivity control is then adjusted to bring the needle to the correct point on the scale.

The advantages of the "Filmeter" are the fact that spot readings may be taken at almost any angle, the large thickness range which may be measured, and the speed with which determinations may be made. The accuracy of measurement is about 5 per cent. The meter operates on a 200–250V, 50 c/s supply, or can be supplied for battery operation.

The Fielden Proximity Meter is another instrument which in effect measures capacitance. It is not designed specifically for use with paint films, but may be used for a great variety of applications where the property to be measured may be translated into a capacitance effect. For example, it may be used for the detection of strains in metal structures or very small changes of length, or mechanical displacements, such as liquid levels. Where one is dealing with non-conductors, such as paint films, where the composition is constant, the change in capacitance may be interpreted in terms of thickness, as in the "Filmeter." Alternatively, where the thickness is constant, it may be used to detect changes in composition. Although it measures capacitance changes and is employed in practice in a manner similar to that used for the "Filmeter," the Fielden meter has a different design of electrical circuit. It measures the capacitance of the paint film relative to earth by balancing it against an adjustable reference capacitance, which is also earthed. The change in capacitance resulting from the introduction of the paint film produces a small out-of-balance voltage, whose scale is calibrated in terms of the thickness of the paint film.

As in most thickness meters, the scale of the meter must be calibrated in an empirical manner for each particular application by the use of a known thickness of paint of the same composition. This calibration is rapidly done by first setting the zero of the meter for the particular electrode in use, and then adjusting the sensitivity to suit the thickness and composition of the film under examination. Normally, the full sensitivity of the meter is not required for work with paint films. It is capable of detecting a change of capacitance of one hundred-millionth of a microfarad, but such a value would be much below that of any practicable thickness of film. The sensitivity can be adjusted to give a full-scale deflection for 0·1 mil if required, although for most applications a full-scale deflection for 5 mils would suffice. The accuracy and reproducibility of the meter readings are claimed to be about 1 per cent, which is greater than that of any industrial thickness meter. The original type "PM 1" meter had no means of stabilising the input voltage, and it has been found that variations of input voltage caused inaccuracies in measurement. In the recently introduced model "PM 2," this disadvantage has been removed by the addition of a voltage stabilising pack.

The meter may be used for almost any shape and size of painted surface, provided a suitable measuring electrode is used. For flat surfaces, the electrode takes the form of a flat plate; for curved surfaces, however, a ball-shaped electrode should be used.

Radiation Thickness Gauges

The newest approach to the problem of coating thickness measurement is the use of radiation from radio-active sources. The operation of atomic piles has made available a considerable variety of radio-active materials, of which one or two can be used in thickness meters. X-rays had already been used in a manner similar to that employed with radio-active materials, and in the present stage of development in this field the two kinds of gauge may be regarded as complementary. For convenience the two kinds of gauge will be designated X-ray and radiation gauges to distinguish one from the other, although, of course, they are both strictly speaking radiation gauges. It might be thought that with so many different kinds of thickness gauge now in production, a new one would be superfluous. However, radiation gauges have features not shared by other methods of measurement; they do not necessitate mechanical contact with the test material and can be used therefore for coatings on moving objects. Up to the present they have found their greatest application in paper and steel rolling mills where the nature of the process involves the continuous production of a web of paper or steel strip from the mill. Their use in these applications has progressed further than in the measurement of paint coatings, where their use is still under development. They also offer the possibility of relatively high sensitivity, thus making it possible to measure thinner films than is possible with most other types of gauge.

Radiation gauges at present on the market utilise either beta or gamma radiation. The former radiation is obtained at present from a radio-active isotope of thallium, known as thallium 204. The choice of source is at present severely limited by the availability of materials of suitable life, energy and kind of radiation. It is hoped that another source, strontium 90, will be soon added. There are two classes of radiation thickness gauge, the transmission gauge and the reflection or back-scatter gauge. In the former, the thickness is measured in terms of the proportion of the incident radiation that is absorbed after complete passage through the material under test; in the latter, it is the proportion of the radiation that is absorbed by the layer of material immediately below the surface on which the radiation impinges which is measured. Thus, in the former kind of gauge, the radiation source and the detector head are on opposite sides of the test sheet, while in the latter they are on the same side.

Of these two classes of gauge, the reflection gauge is the one which would be chosen for the measurement of the thickness of thin coatings on a base material, for reasons mentioned below; the transmission type of meter is more suitable for use where it is a question of the determination of the total thickness of a sheet. The ability of a gauge of this kind to discriminate between the coating and the base depends on the difference between the absorptive power of the two materials. It will be appreciated, therefore, that with a transmission gauge, unless the absorptive power of the coating is vastly different from that of the base, or the thickness of the coating is comparable with that of the base, its contribution to the total absorption will be small, and the sensitivity of the gauge for the measurement of the coating thickness will also be small. In point of fact, the degree of absorption of the radiation energy by a given thickness of material is proportional to its atomic number; the gauge is therefore in essence a composition meter, and is capable of being used as a thickness meter only so long as the composition of the coating does not vary to a serious extent in any given application.

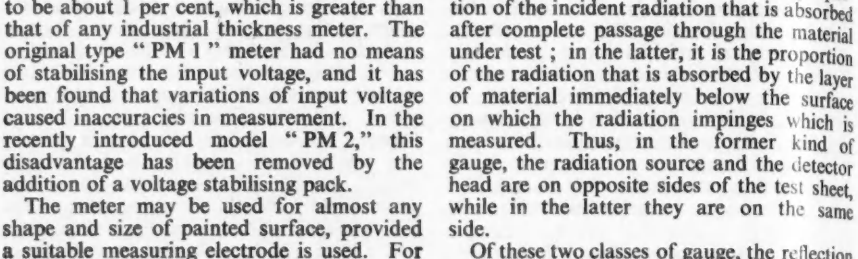

Fig. 10—Beta Absorption Gauge Showing Head and Console

In the reflection or back-scatter radiation gauge, the fraction of the incident radiation absorbed is directly proportional to the thickness of the absorbing layer, for thicknesses of backing material such that the combined fractions of the incident radiation reflected and absorbed total less than 80 per cent.

Tracerlab Inc., of Boston, U.S.A., manufactures a thickness meter (Fig. 10) which may be regarded as typical of the reflection type of radiation thickness meter. It embodies a source of beta radiation—for most purposes, a salt of thallium isotope 204 deposited on a flat dish; a detector unit for receiving

the radiation after passage through the coating; an amplifier for magnifying the current from the detector head, and an indicating meter or recorder for measuring and expressing the amplified current in terms of thickness. The detector head consists of a cylindrical ionisation chamber of more or less conventional design mounted on the same side of the test material as the source. To reduce the risk of drift of the readings and to increase the sensitivity of the meter, a null method of measurement is used, as is commonly done where very small outputs of electrical energy are being handled. To this end, a second radiation source is placed inside the ionisation chamber to act as a reference source, and may be adjusted to cancel the effect of the radiation from the first source at a selected coating thickness. Deviations from this thickness are thus measured as the differences in the intensities of the radiations from the two sources.

The advantages of this class of gauge are its good sensitivity and its suitability for the measurement of thickness when access may be had to only one side of the work-piece. A full-scale sensitivity of plus or minus 5 per cent of the thickness may be achieved, and for larger thicknesses a variation of plus or minus 1 per cent may be detected. It is capable of a rapid response to changes in thickness, and the readings of the instrument are not affected by the roughness of the surface of the film. Both wet and dry coatings may be measured.

At present the usefulness of this kind of radiation thickness gauge for paint coatings is rather limited by the low energy and penetration power of the radiation emitted by thallium 204. For a back-scatter gauge, the effective range expressed in terms of density is 0·75 mg. per square centimetre; for a paint film with an assumed density of 2 g. per cubic centimetre, this range corresponds with a maximum thickness of about 10 mils. On the debit side, also, must be set the fact that the sensitivity of the gauge falls with time as the radioactive source decays; for this reason, recalibration of the meter with standards of known thickness is necessary at intervals of about a month. As the source is about 3in in diameter, the gauge measures the average thickness over a corresponding area.

There are several other radiation transmission thickness gauges in production, including the "Atomat" back-scatter gauge made by the Baldwin Instrument Company, Ltd., of Dartford, Kent, and illustrated in Fig. 11, but it should be made clear that none is yet fully proved for use with paint films and further development work is necessary.

Because of the present limited range of meters employing radioactive isotopes, the interest of the X-ray type of meter lies largely in the possibility it offers of extending the thickness range because of the more penetrating radiation which may be generated from an X-ray tube. This class of meter has had only a very limited use for paint films, but should be mentioned for the sake of completeness.

An X-ray back-scatter gauge made by the Baldwin Instrument Company, Ltd., of Dartford, Kent, has a range of 0–300 mgms. per square centimetre, equivalent to a maximum thickness of coating of about 40 mils. A back-scatter gauge has also been described by H. Friedman and L. S. Birks of the U.S. Naval Research Laboratory at Washington, for films ranging in thickness from 0·004 to 4 mils. The advantages claimed for this gauge are that it may be used for metallic or non-metallic coatings on either kind of base, and may be applied to multi-layer coatings over either large or small areas. In the Birks and Friedman gauge a slightly divergent pencil of X-rays is directed upon the flat surface of the specimen, from which it is reflected into a Geiger-Muller counter for the measurement of the intensity of the reflected beam. The thickness may be determined from the ratio of the intensities of the incident and reflected beams, the reflection angle and the mass absorption coefficient, but it is simpler to calibrate the instrument by the use of films of known thickness. As the angle between the incident and reflected beams is the Bragg diffraction angle for the base material on which the paint film is supported, provision must be made for the adjustment of the angular position of the Geiger-Muller tube to suit the composition of this material, and the accuracy of measurement is much affected by the precision of the setting of the holder in which the specimen is mounted. From this it may be inferred that this instrument is more suited for research work in the laboratory than for routine industrial use.

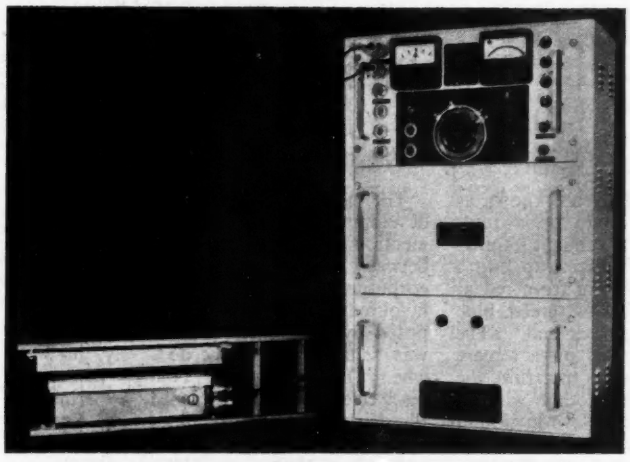

Fig. 11—" Atomat " Industrial Gauge and Measuring Head

Comparison of Thickness Meters

In development work for the preparation of Tentative Method D 1005–49 T† for the measurement of dry film thickness, a committee of the A.S.T.M. under the chairmanship of E. J. Dunn, Jr., recently organised a comparison of several different kinds of gauge by a number of laboratories. These instruments included the magnetic attraction, inductance, and impedance meters, and micrometers. This study indicates that more than one gauge must be available if the most accurate results are to be obtained over all thickness ranges. Of the instruments tested it was decided that the dial micrometer was the most suitable method to be the basis of a specification for film thicknesses greater than 0·5 mil; besides being inexpensive, it gave results within 0·1 mil of the true thickness that were a fair average of the results obtained with the other meters. The measurement of thicknesses below 0·5 mil was found to be a more difficult problem. For this range the Brenner "Magne-Gage" was recommended as giving the most consistent results, although those obtained with the International General Electric gauge were almost as good. The weight-density method was examined for films in the latter range and was found to have no advantage to compensate for its complexity and time-consuming nature. Difficulties were encountered with most machines with thicknesses below 0·1–0·2 mil and emphasised the need for an adequate technique. Errors arose with tacky films because of compression by micrometer spindles.

The study made by the committee of the A.S.T.M. revealed the effect of the personal factor on the results obtained by different observers with the same gauge. In particular it showed the importance of careful calibration of an instrument for accurate results. The results of measurements made on carefully prepared reference standards showed that apparent discrepancies between machines could be largely brought into line by proper calibration.

The question of calibration presents rather peculiar difficulties with some kinds of gauge, in particular when they are to be used for the measurement of very thin films. The most effective method of calibration appears to be the use of standard films, foils or gauge blocks of curately known thickness; they must be selected to suit the type of gauge under consideration. It is worth pointing out that such reference films or blocks are in effect secondary standards; their preparation presupposes, however, the use of some method of measurement having greater accuracy than can be achieved by the thickness gauge to be calibrated. For very thin films, however, micrometer readings are not very accurate so the best resources of the engineering industry must be called into play. To obtain the required accuracy makes a demand upon the more accurate methods of the engineering industry, such as the optical comparator.

There are two well-known series of standards generally available for gauge calibration, those prepared by the National Bureau of Standards, and a set of Johannson gauge blocks. For the investigation made by the A.S.T.M. committee already mentioned, the N.B.S. prepared a special series of standards for use with the very thin coatings of 0·1 to 0·2 mil thickness. For the measurement of non-magnetic coatings, metallic standards are unsuitable; hence the International General Electric Company supplies thin celluloid films for the calibration of its enamel thickness gauge.

A popular method for the production of standards for the calibration of gauges used with non-magnetic coatings is the preparation of chromium platings of known thickness on mild steel by electro-deposition. To obtain the desired smoothness and uniformity of plating thickness over a standard with the necessary minimum area of 2 to 4 square inches, it is usual to plate as large an area of steel sheet as possible, and then cut from it portions 2in square. These smaller pieces should be checked for uniformity, and then the thickness measured by some other method. This may be a micrometer if the thickness is not less than a mil, or by a chemical method for the determination of the chromium after removal from the steel. This method has the necessary accuracy for calibration, but would, of course,

† A.S.T.M. *Bulletin*, February 1951, pages 35-39.

be far too tedious for routine measurements of coating thickness.

Scope for Improvement

From the comments which have been made in the above discussion of the various thickness gauges, it will be realised that the truly universal instrument has not yet been produced and that there is still considerable scope for improvement. The fact that new instruments continue to be introduced, is a strong indication that the all-purpose instrument is not with us. However, the introduction of new designs of meter does not necessarily mean that the earlier instruments are unsatisfactory for the purpose for which they were designed, and that they have now been superseded by newer models. The need for new designs arises to a large extent from the greater variety of problems presented by modern conditions in the protective coatings industry. For many situations the older gauges give satisfactory results ; whether or not the user feels the need for newer methods depends on the type and variety of problems encountered in the work in hand.

Factors such as the size and shape of the base to which the paint film has been applied, the thickness and properties of the coating and of the base metal, the accessibility to one or both sides of the work, or whether the material is stationary or in movement, all have an important bearing on the design and choice of instrument. The kind of finish used is also very significant. The best thickness for protection against corrosion may vary widely with the kind of finish applied and the purpose for which it is employed. One user quotes extremes of 5 to 6 mils for vinyl, phenolic and alkyd coatings, and 60 to 75 mils for gilsonite-asphalt mastic. Thus, where the coating is applied under very restricted conditions, the user might be satisfied with an instrument which would hamper the activities of a manufacturer faced with a larger variety of problems.

A Short History of Spectroscopy

By T. W. CHALMERS, D.Sc., M.I.Mech.E.

No. I—THE EARLY DAYS OF SPECTROSCOPY

THE branch of physical science known as spectroscopy owes its origin to Newton's observation that a pencil of sunlight impinging on a glass prism was broken up into a series of coloured rays ranging from red at one end through orange, yellow, green, blue and indigo to violet at the other end.* The dispersed rays, when received on a screen, appeared to form a continuous spectrum, the colours merging into one another without visible separation. Later, Newton found that a second prism suitably disposed relatively to the first recombined the dispersed rays into the original white light.

The conclusion was drawn that sunlight consisted of a mixture of differently coloured rays which were bent or refracted through different angles when they passed through a glass prism. More analytically the dispersion could be explained on the supposition that when light passed from air into glass its velocity was slowed down to an extent depending upon its colour, the retardation being greatest in the case of violet and least in the case of red light. The reverse process took place when light passed from glass into air. Consequently, when light passed through a plane sheet of glass the rays dispersed at the incidence surface were reunited into white light at the emergence surface. If, however, the two surfaces were not parallel, as in a prism, the rays, dispersed at the incidence face, would fail to reunite into white light at the emergence face by an amount determined by the inclination of the two faces, that is to say, by the prism angle. A spectrum of colours would therefore appear on the emergence side of the prism.†

Parenthetically it may be noted that Newton, adhering to the corpuscular theory of light, argued that different colours were composed of corpuscles of different sizes. It was therefore natural to assume that, in traversing glass, corpuscles would be retarded to different degrees, determined by their size. The inference was that the violet corpuscles were larger than the red.

The next 130 years or so produced no development of spectroscopy worthy of mention, except for a bitter controversy between those who believed in Newton's corpuscular theory of light and those who favoured the undulatory ether theory, proposed by Hooke and others. That dispute was settled, apparently decisively, in 1801 when Dr. Thomas Young performed his celebrated interference experiments. Physicists accepted the results of Young's experiments as establishing the truth of the undulatory theory and totally discrediting the corpuscular theory. A new explanation of the difference between one colour and another had naturally to be found. It was assigned to a difference in the wavelengths of the undulatory motion.

It would be incorrect to say that Young's experiments originated the very remarkable developments in the field of spectroscopy which occurred during the nineteenth century. Actually that period of intense and fruitful activity began a year earlier with a discovery which was quite independent of the undulatory *versus* corpuscular controversy. In 1800 William Herschel placed a sensitive thermometer in different parts of the solar spectrum and observed the rise of temperature. He found that the greatest rise was shown when the thermometer was placed in the red rays of the spectrum and least when it was situated in the violet rays, the ratio being almost 4 to 1. Then came a very surprising result. Placing the thermometer well beyond the visible red end of the spectrum, Herschel found that it registered a still higher temperature, the ratio becoming nearly 5 to 1. It was evident, therefore, that the visible solar spectrum extended at the red end into an invisible region in which the rays had the character of heat rather than of light.

In 1801 Ritter made a corresponding discovery at the other end of the solar spectrum. The fact that paper coated with silver chloride was blackened by exposure to sunlight was already known.‡ Ritter placed a piece of paper so coated in different parts of the solar spectrum and studied the blackening effect. It was almost absent at the red end and greatest at the violet end. Moving the paper beyond the violet rays and shielding it from the visible rays Ritter found that the blackening effect was even stronger than that of the violet rays. The visible solar spectrum therefore extended at the violet end into an invisible region in which there were rays possessing enhanced blackening activity or, as we would now say, enhanced photo-actinic power.

Ritter's discovery was the complement of Herschel's. In addition it provided the basis for the subsequent study by photographic means of the spectrum in the ultra-violet region.

Thus at the very opening of the nineteenth century the existence of both the infra-red and ultra-violet extensions to the visible solar spectrum was established. Young's demonstration of the undulatory character of visible light naturally suggested that the invisible infra-red and ultra-violet rays were of the same nature and that they differed from visible light solely as regarded their wavelengths. It was easy to believe that the ultra-violet rays were simply a form of light which the human eye could not see. It was less easy to accept the same view regarding the infra-red rays. They were clearly a form of heat—radiant heat—and therefore, according to the caloric theory, ought to consist of a stream of material particles. How could the infra-red rays be simultaneously corpuscular and undulatory ?

The calorists were perplexed. Yet in one respect the similarity between radiant heat and visible light had long been known. Both could be reflected by means of concave mirrors. There was the story of Archimedes

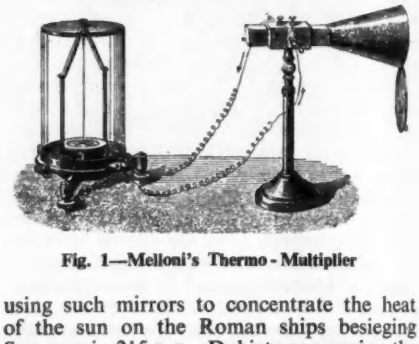

Fig. 1—Melloni's Thermo-Multiplier

using such mirrors to concentrate the heat of the sun on the Roman ships besieging Syracuse in 215 B.C. Dubiety concerning the probable truth of that legend had been removed by Buffon in Paris in 1747. Reporting to the Royal Academy of Sciences, he recorded that using Archimedes' method he had set fire to wood at a distance of 150ft and had melted lead at a distance of 140ft.

During the decade 1830–1840 other direct testimony as to the fundamental identity of radiant heat and visible light was forthcoming.

Following Seebeck's discovery of thermo-electricity in 1821, Nobili and Melloni invented the " thermo-multiplier." Melloni's form of this device—Fig. 1—consisted of an arrangement of thermo-couples at the end of a collecting cone and a galvanometer to measure the induced current. The thermo-couple element comprised a number of antimony and bismuth bars grouped alternately to form a square cross-section, the bars being connected at opposite ends, with insulating pieces of mica between them elsewhere. When radiant heat was directed into the cone this instrument enabled temperature to be measured with a hitherto wholly unattainable degree of accuracy.

In succeeding years Melloni's " thermo-multiplier " was to be developed into one of

* The exact date on which Newton made this observation is uncertain. W. W. Rouse Ball suggested that it may have been in 1665 or 1666, when Cambridge University was closed down because of the plague. Newton, then about twenty-three years of age, had to return to his Lincolnshire home and continued his studies in private. The public announcement of the discovery was made in February, 1672, before the Royal Society.

† A fuller discussion of the prism will be given later.

‡ Boyle in 1663 noticed the blackening of silver chloride, but attributed it to the action of air on the salt. In 1777 Scheele found that violet rays darkened the chloride much more quickly than the rays in other parts of the spectrum. He argued that all the rays contained phlogiston and that the violet rays parted with it more readily than the others.

the principal means of studying the infra-red spectrum. The first discovery made with its aid by Melloni was, however, the fact that rock salt was transparent to radiant heat. Making prisms and lenses of this substance he then proved that radiant heat could be refracted just like visible light. Shortly afterwards, in 1834, Professor James Forbes, of Edinburgh, using a thermo-multiplier and crystals of tourmaline, showed that radiant heat could be polarised in the same manner as visible light.

With these facts before them physicists could argue with reasonable assurance that radiant heat, visible light and the photo-actinic radiations were all fundamentally of the same nature. They were all manifestations of undulatory motion and differed from one another only as regarded the wavelengths associated with the motion. The fact that the three forms of undulatory radiation affected our senses differently was merely incidental to the limitations of the powers of observation with which Nature had endowed the human body.

In later years further evidence as to the basic identity of radiant heat with visible light was discovered. Radiant heat, it was found, could, like light, exhibit the phenomena of interference and diffraction. Also observations made during solar eclipses showed that the radiation of heat from the sun ceased at the same instant as the radiation of light. Radiant heat and light were therefore propagated, in a vacuum, with the same velocity.

Accepting radiant heat as a form of invisible light, let us now return to the early years of the nineteenth century and note how the science of spectroscopy developed following Herschel's and Ritter's vital discoveries.

Young's interference experiments of 1801 did more than provide testimony to the soundness of the undulatory theory of light ; they permitted the wavelength of the undulations to be calculated. Young, using a diffraction grating§ ruled with 500 lines to the inch, reported that the red rays of the visible solar spectrum had the longest wavelength—about 25 millionths of an inch—and the violet rays the shortest—about 17 millionths.

In 1802 Dr. Wollaston made an observation which later was to become of deep significance. Admitting sunlight into a darkened room through a slit only about $^1/_{20}$in wide and standing about 12ft away from the slit, he examined the beam through a flint glass prism held close to his eye. He observed that some of the colours were separated by distinct dark lines. The solar spectrum, it appeared, was *not* completely continuous as Newton had supposed. Wollaston's discovery of the discontinuities represented by the dark lines can be assigned simply to the narrowness of the slit through which he admitted the light and to the distance from it at which he held his prism. Under similar circumstances Newton might have noticed the dark lines in the solar spectrum.

In 1817 Joseph Fraunhofer, a physicist and practical glass worker of Munich, developed the first arrangement of parts to which the name " spectrometer " can properly be applied, that is to say an arrangement which not only permitted spectra to be observed, but allowed accurate measurement to be applied to them. Into a darkened room he admitted a beam of sunlight through a narrow slit. The beam was directed on to a flint glass prism situated about 24ft from the slit. The prism was mounted on a rotatable base in front of a theodolite—see Fig. 2—through the telescope of which the spectrum was observed. By means of the divided circle of the theodolite the angular dispersion of the different rays composing the spectrum could be measured. A modern spectrometer differs basically from Fraunhofer's arrangement only in so far that in order to economise space the slit is fixed at the end of a second telescope—known as the " collimator "—which is mounted on the theodolite base. The light passing through the slit is directed as a parallel beam by the collimator on to the prism. The use of a

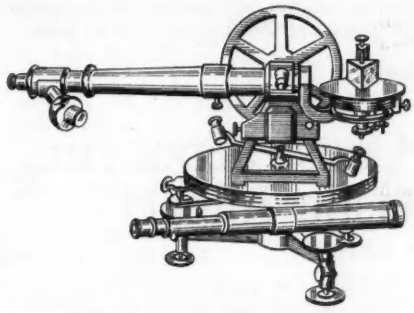

Fig. 2—Fraunhofer's Spectrometer

collimator may be regarded as equivalent in Fraunhofer's arrangement to the employment of a slit at practically an infinitely great distance from the prism.

Through the telescope of his theodolite Fraunhofer observed that the solar spectrum was crossed by not merely a few dark lines, as Wollaston had noticed, but by very many—see Fig. 3. The lines varied in intensity of darkness down almost to full black. Fraunhofer lettered the principal lines from *A*—in the red—to *H*—in the violet. Line *D*, in the yellow, was very prominent and on close examination was seen to consist, not of one, but of two strong dark lines lying close together. Line *E* was a strong dark line in the green. Between *D* and *E* Fraunhofer counted about eighty-four subsidiary lines of various degrees of darkness.

Examining the light received from Venus, Fraunhofer found that its spectrum was the same as, although weaker than, that of sunlight. He could distinguish the lines *D*, *E* and *F* quite readily. They were in the same positions as in the solar spectrum. These observations were to be expected ; the light received from Venus was merely reflected sunlight.

Turning to the light received from the star Sirius, Fraunhofer observed that its spectrum, although weak, was definitely different from that of sunlight. Sirius did not reflect the light of the sun ; it was self-luminous. Thus began the very extensive and highly fruitful applications of spectroscopy to astronomical science.

Among other discoveries which Fraunhofer made at this time was one of fundamental importance, but of which he could not immediately see the explanation. Examining the spectrum produced by the light from a spirit lamp, he found that no dark lines were present. Instead there was a conspicuous *bright* yellow line. On closer study this line was resolved into two bright yellow lines close together. They were exactly in the same positions as the two closely adjoining *dark D* lines in the solar spectrum.

The explanation of this curious observation was provided by an experiment performed in 1832 by Sir David Brewster. Examining the spectrum obtained when the light from a spirit lamp was passed through an atmosphere of nitrous acid gas before reaching the prism, Brewster found that it was crossed by hundreds of dark lines which were far more distinct than those in the solar spectrum. He knew that nitrous acid gas rendered luminous by the application of heat to it yielded a spectrum consisting of numerous distinctly separated bright lines. These bright lines tallied in position with the dark lines observed when the gas, instead of being made self-luminous by heat, was used merely as an intermediary for the transmission of the light from his spirit lamp. Brewster argued that the dark line, or transmission, spectrum was produced by the suppression or absorption of certain rays by the nitrous acid gas and that the rays which it selected for absorption were those which produced the corresponding bright lines of its self-luminous, or emission, spectrum.

Brewster extended this argument to an explanation of the dark lines in the solar spectrum discovered by Fraunhofer. He contended that the light emitted by the sun was in its original state such as to give a truly continuous spectrum, that was to say that it contained rays of all wavelengths. Before it reached us, however, it had to pass through two gaseous atmospheres, the sun's and the earth's. Each atmosphere, according to its composition, would absorb certain of the rays with the resultant production of dark lines.

It had earlier been established—largely by experiments performed in 1826 by Fox Talbot—that the bright double yellow line

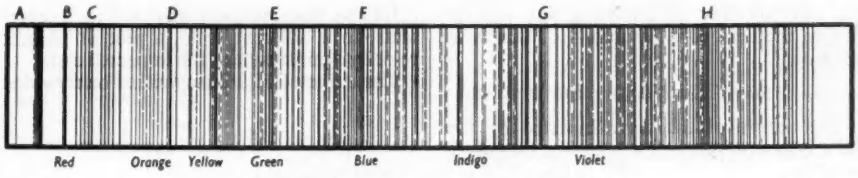

Fig. 3—Solar Spectrum as seen by Fraunhofer

seen by Fraunhofer in his spirit lamp spectrum was produced by and characteristic of the element sodium and that a minute trace of it must have accidentally been present in the spirit lamp flame.‖ It was therefore evident, Brewster argued, that the coincidence of Fraunhofer's two bright yellow sodium lines with the two dark *D* lines of the solar spectrum was to be explained on the supposition that sunlight before reaching us passed through a cloud or envelope of sodium vapour.

It is now known that certain of the dark lines in the solar spectrum are produced by the absorption effect of the oxygen and nitrogen of the earth's atmosphere. There is, however, no doubt about the origin of the two dark *D* lines. They are produced by the absorptive effect of sodium vapour in the sun's atmosphere. This conclusion is based on observations of the solar spectrum made at different times of the day. At all times the two *D* lines remain unaltered in position and intensity. If the sodium vapour were present in the earth's atmosphere an alteration in the sodium lines would have been revealed as a result of the greater thickness of the sodium

§ The theory of the diffraction grating will be dealt with later.

‖ In spectroscopy sodium is found to be almost ubiquitous. A minute trace of it is nearly always present in all substances examined. Fortunately, the two double yellow lines characteristic of its spectrum are so prominent and so exactly defined in their position that their presence introduces little confusion.

vapour layer traversed by the light of the sun towards evening as compared with that at noon.

This deduction was confirmed when the spectrum of the light from one limb of the sun was compared with that from the other. The rotation of the sun—or more precisely the rotation of that part of its atmosphere containing the sodium vapour—should produce a Doppler effect on the sodium *D* dark lines. They should shift their positions, those in the light coming from the advancing limb indicating an apparently shorter wavelength than those from the receding limb. Experimental results harmonised with this argument. In passing it may be noted that from the observed shift of the *D* lines and from the theory of the Doppler effect it was possible to calculate the velocity of rotation of the sun. The calculated results agreed with the conclusion reached as long ago as 1613 by Galileo from his observations of the movement of the sun's spots across its disc. The sun did not rotate like a solid body; its angular velocity was greatest at its equator and decreased markedly towards its poles.

(*To be continued*)

The Phase-Plane Construction in Problems of Elastic Impact

By R. E. D. BISHOP

The phase-plane construction for transient disturbances of linear systems can be applied, mode by mode, to a wide variety of vibrating elastic structures. By using the principal co-ordinates of longitudinal vibration of a rod, a problem of the Hopkinson pressure bar is analysed by mode superposition using the elementary wave theory as a check. The particular case of the propagation of a stress wave in a bar has been selected as one for which the results are themselves of some interest.

WHEN the end of an elastic bar is given an axial blow, a pulse of pressure is set up which is propagated through the material. Hopkinson[3] used this as the basis of a device for measuring the intensities and durations of violent impacts and one of his results will be discussed here.

Assuming that longitudinal displacements u of the bar are governed by the simple equation :

$$c_o^2 \frac{\partial^2 u}{\partial x^2} = \frac{\partial^2 u}{\partial t^2} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

the obvious way of analysing the motion due to the impact is by means of the wave solution,

$$u = f_1(x + c_o t) + f_2(x - c_o t) \quad . \quad . \quad (2)$$

The nature of the wave initiated by the blow is determined by the transient boundary condition.

The alternative approach, involving normal modes, is more cumbersome, but it is quite straightforward and affords an interesting comparison with the usual wave theory. This form of solution can easily be examined by the phase-plane method.

Suppose that a 1in diameter steel bar of length 4ft is subjected to an impulsive force P of the form shown plotted against time in Fig. 2. This bar is, effectively, the one used by Hopkinson (loc. cit.), while the nature of the impulse was calculated by him to represent the impact of a lead bullet. The validity of this curve does not concern us here, but it is discussed by its author. We shall consider the displacements of the bar after the elapse of some specified length of time.

The Wave Solution

According to the theory of equation (1) (e.g. see Timoshenko and Goodier[6]), the stress is given by $\sigma = P/A = E\partial u/\partial x$. Thus, equation (2) shows that, within the stress wave, particle velocity bears a constant relation to stress, viz.:

$$\frac{\partial u}{\partial t} = v = \frac{c_o \sigma}{E} = \frac{c_o P}{AE} = 7{\cdot}22 \times 10^{-4} P \quad . \quad . \quad (3)$$

It follows that the curve of P in Fig. 2 represents, to a different scale, a plot of particle velocity against time at the impacted end.

The curve of Fig. 2 may either be regarded as showing the variation of P (or v) with time at a section of the bar or of P (or v) with x at any instant during transit of the ensuing wave. This is an obvious conclusion to be drawn from the non-dispersive nature of the motion, the constant of proportionality between abscissæ of space and time being c_o.

The variation of v with x may now be plotted for a given instant. It is shown dotted in Fig. 1 for an instant $11{\cdot}77 \times 10^{-5}$ sec after the initiation of impact.* Corresponding to a time τ in the curve of Fig. 2, the ordinate is given by equation (3) and the abscissa is $\chi = 17{,}000(0{\cdot}0001177 - \tau)$ ft in

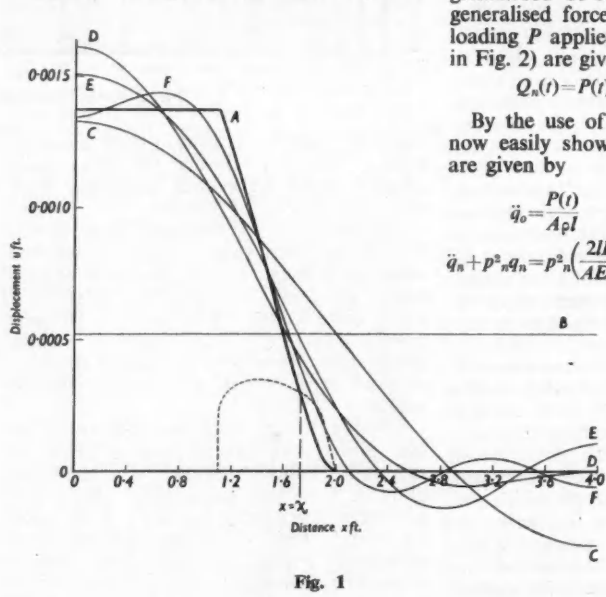

Fig. 1

Displacements due to the passage of the wave are now easily found by integration. For instance, at the section $x = \chi$,

$$u = \int_o^\tau v\,dt = 7{\cdot}22 \times 10^{-4} \int_o^\tau P\,dt \quad . \quad . \quad . \quad (4)$$

evaluated by counting squares under the curve of Fig. 2. In this way, the displacement curve *A* of Fig. 1 was found.

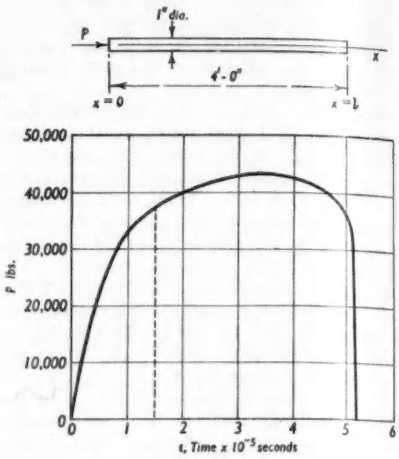

Fig. 2

The Normal Mode Solution

The displacements of a "free-free" bar of length l can be expressed in terms of the normal functions $\cos n\pi x/l$. Thus :—

$$u = \sum_n q_n(t) \cos \frac{n\pi x}{l} \quad (n = 0, 1, 2 \ldots) \quad . \quad (5)$$

where the quantities q_n may be taken as generalised co-ordinates. The appropriate generalised forces Q_n corresponding to the loading P applied at the point $x = 0$ (shown in Fig. 2) are given by

$$Q_n(t) = P(t) \quad (n = 0, 1, 2 \ldots .) \quad . \quad (6)$$

By the use of Lagrange's equations, it is now easily shown that the co-ordinates q_n are given by

$$\left.\begin{aligned} \ddot{q}_o &= \frac{P(t)}{A\rho l} \\ \ddot{q}_n + p_n^2 q_n &= p_n^2 \left(\frac{2lP(t)}{AE\pi^2 n^2}\right) = p_n^2 \Omega_n, \text{ (say)} \end{aligned}\right\} \quad . \quad (7)$$

where $p_n^2 = c_o^2 \pi^2 n^2 / l^2$ and $n = 1, 2, 3 \ldots$ (e.g. see Timoshenko[6]). The functions of time on the right-hand sides of these equations are all known, since $P(t)$ is defined by the curve of Fig. 2.

Double integration of this curve (by counting squares) and use of the first of equation (7) gives $q_o = 0{\cdot}000520$ft for the rod under discussion when $t = 11{\cdot}77 \times 10^{-5}$ sec. (On checking it is found that this accurately coincides with the mean ordinate of curve *A* of Fig. 1, as it should.) This accounts for the "rigid body" term of the

* This length of time has been selected as that during which a point of the wave will travel a distance equal to half the length of the bar.

Notation

A—Area of bar $= \pi/4$in^2.
c_o—Speed of longitudinal waves $= \sqrt{(E/\rho)} = 17{,}000$ft/sec.
E—Young's modulus $= 30 \times 10^6$ lb/in^2.
l—Length of bar $= 4$ft.
n—Mode number.
P—Applied force, lb.
p_n—Circular frequency of n^{th} mode $= c_o \pi n/l$.
Q_n—Generalised force for n^{th} mode.
q_n—Generalised co-ordinate for n^{th} mode.
r_n—n/p_n.
R—See Fig. 3.
t—Time, sec.
u—Longitudinal displacement, in x direction, ft.
v—Particle velocity, ft/sec.
x—Distance along bar, ft ($0 < x < l$).
α—See Fig. 3.
ρ—Mass density $= 482$ lb/ft^3 or 15 slugs/ft^3.
σ—Longitudinal stress $= P/A$ lb/in^2.
Ω_n—Function of time $= 2lP(t)/AE\pi^2 n^2$.

series representation (5) and is shown as curve B in Fig 1. Other co-ordinates q_n can be handled by the phase-plane technique.

The Phase-Plane Technique for Transient Vibrations

Dropping the subscript n temporarily, let us examine the equation

$$\ddot{q}+p^2q=p^2\Omega \quad . \quad . \quad . \quad . \quad . \quad (8)$$

where Ω is a function of t.†

Noting that $\ddot{q}=\dot{q}(d\dot{q}/dq)$, it is easily shown that equation (8) may be written

$$\frac{dq}{dr}=\frac{r}{\Omega-q} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where

$$r=\frac{\dot{q}}{p} \text{ or } \frac{1}{p}\frac{dq}{dt} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

In this way the original second order equation (8) is replaced by two first order equations ((9) and (10)) and the geometric

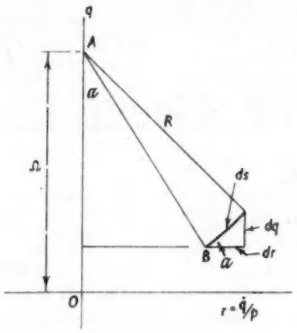

Fig. 3

implications of the latter admit of a simple graphical solution of the former.

Equation (8) may be regarded as that of a simple oscillator with transient forcing so that, at any instant, the state of the system is defined by q and $\dot{q}$. This state is defined by a "representative point" moving in the $q-r$ plane (called the "phase-plane") and the nature of its path (or "trajectory") is determined by equations (9) and (10), as shown in Fig. 3.

The first indicates that the trajectory at any point B in the plane is perpendicular to the line AB joining that point to the point $q=\Omega$ since the two angles marked α tend to equality as dq and dr are diminished, i.e.

$$\tan\alpha=\frac{r}{\Omega-q}=\frac{dq}{dr}.$$

Next, equation (10) defines the angular velocity with which the radius AB rotates about the instantaneous centre A. For, in the limit

$$\sin\alpha=\frac{r}{R}=\frac{dq}{ds},$$

so that

$$\frac{ds}{R}=\frac{dq}{r}=pdt,$$

showing that the angular velocity is p, a constant.

In using the graphical method, steps are taken in Ω rather than a continuous variation, the curve of Ω against t being replaced by a series of steps for the purpose during each interval of which Ω remains constant. Usually it is found that sufficient accuracy can be obtained when the angles subtended at the $q-$axis $(=pdt)$ are less than about 40 deg. The variation of q (or of r) with t can be found by projection. A concrete example is given in the next section, where the solutions of equation (7) are treated while a general examination of the technique and the literature concerning it is given by Bishop[2].

† The general case in which Ω depends on q, $\dot{q}$ and t is discussed by Jacobsen[1].

Graphical Solutions for the Generalised Co-ordinates q_n

Using data given concerning the bar under consideration,

$$p_n=\frac{17{,}000\pi n}{4}=13{,}400\,n \text{ (approx.)}$$

$$\Omega_n=\frac{2\times4}{(\pi/4)\times30\times10^6\pi^2}\left(\frac{P}{n^2}\right)=3\cdot44\times10^{-8}\left(\frac{P}{n^2}\right) \text{ (approx.)}$$

in equation (7).

With these values, let us take up the case where $n=1$. The curve shown in Fig. 5 is that of $3\cdot44\times10^{-8}P$ plotted against t and is obtained from Fig. 2. It is shown divided into steps of duration 1×10^{-5} sec. from 0 to 5×10^{-5} sec., followed by a step of $0\cdot2\times10^{-5}$ sec. The appropriate angles pdt in the phase plane are thus :—

$$13{,}400\times10^{-5}=0\cdot134 \text{ radians or } 7\cdot7 \text{ deg. (approx.)}$$

and

$$13{,}400\times0\cdot2\times10^{-5}=0\cdot027 \text{ radians or } 1\cdot5 \text{ deg. (approx.)}$$

respectively. As the bar is initially at rest, $q_1=0$ when $t=0$ so that the representative point starts at the origin. During the period $O<t<5\cdot2\times10^{-5}$ sec., it follows the curved

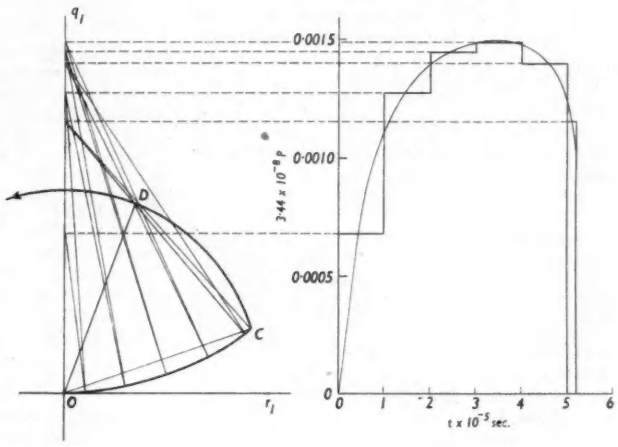

Fig. 5

path OC and, for $t>5\cdot2\times10^{-5}$ sec., the motion is one of free vibration with the centre of the trajectory at the origin. The point D gives the value of q_1 when $t=11\cdot77\times10^{-5}$ sec., the angle COD being $(11\cdot77-5\cdot2)\times10^{-5}\times13{,}400$, or 0·880 radians. The amplitude of the resultant free vibration in the first mode is given by OD $(=0\cdot000865\text{ft})$ and the vertical projection of OD yields $q_1=0\cdot000801$ft when $t=11\cdot77\times10^{-5}$ sec.

The contribution of the first mode to the total deflection when $t=11\cdot77\times10^{-5}$ sec. is thus $0\cdot000801\cos\pi x/l$, and this is plotted as curve C in Fig. 1 on the opposite page.

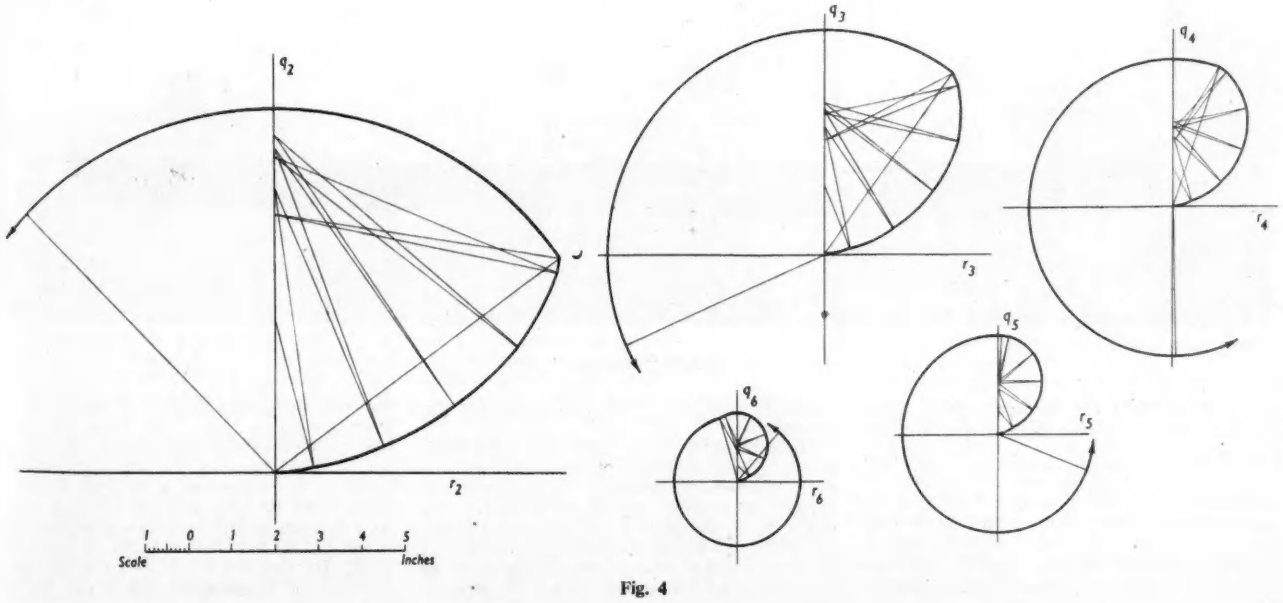

Fig. 4

In the same way, trajectories may be constructed for the $n=2, 3, 4 \ldots$ modes. These are shown (up to $n=6$) in Fig. 4 and the curves for $t=11{\cdot}77\times10^{-5}$ sec. are shown (up to $n=4$ only, to avoid congestion) in Fig. 1 as *D*, *E* and *F*. At that instant

$$u=0{\cdot}000520+0{\cdot}000801\cos\frac{\pi x}{l}+0{\cdot}000285\cos\frac{2\pi x}{l}-0{\cdot}000100\cos\frac{3\pi x}{l}-0{\cdot}000164\cos\frac{4\pi x}{l}-0{\cdot}000040\cos\frac{5\pi x}{l}+0{\cdot}000054\cos\frac{6\pi x}{l}+\ldots.$$

It is to be noted that by using the same time steps (of 10^{-5} and $0{\cdot}2\times10^{-5}$ sec.) the angles pdt gradually increase due to the increase of p_n as n becomes bigger. The presence of the n^2 in the denominator of Ω_n ensures that the modes become less important as n is increased, so that the trajectory for $n=6$ is smaller than that for $n=5$, for instance.

The gradual improvement of the normal mode solution as n is increased is well illustrated in Fig. 1.

Conclusions

When examining problems of elastic impact we have, in general, two lines of attack. The first involves waves defined by functions of a variable combining space and time (e.g. as in equation (2)). Known solutions of this sort are few in number, but, where available, they have the advantage of providing clear pictures of physical states.

On the other hand, mode superposition involves breaking the solution down into separate functions of space and time. Now, an *exact* solution requires the addition of an infinite number of modes and so we must be content with the approximation given by a finite number only. This means that the question of convergence arises, although we will not discuss this here. The important point is that normal mode solutions are generally far easier to find than wave solutions.

Considering the problem of the bar, mode superposition has added attractions. Suppose, for instance, that the impact in the above problem had been of sufficient duration for the wave to have been longer than the bar. The conditions at any point would then be complicated by reflections of the wave at the extremities of the rod. These difficulties become marked in the event of a long impact duration and determination of the conditions at a given point and a given time (by keeping track of the wave) then demands a rather complicated form of bookkeeping. The trajectories (comparable with Fig. 4), however, would give a permanent record of the motion from which the state of the bar at any instant could be read.

Again, the question of damping is much more easily examined by modes. Thus, if we are interested in the state of the bar after the wave front has traversed the bar several times, we can more easily account for the effects of dissipation on the modes than on the wave (see Bishop[2]). Even so, it must be admitted that the specification of the damping for the modes is not without difficulty. The net effect is to increase the preponderance of the gravest mode while killing out the vibration as a whole.

The phase plane has been shown to offer a convenient way of handling a typical impact problem by means of normal modes. This has been done for a system whose wave solution is known in order that a check may be made on the working. The actual results (embodied in Fig. 1) are of textbook, rather than research, value. For they show the equivalence of the two approaches. One point is, perhaps, not obvious. It is that, by adopting a graphical rather than a numerical procedure for solving equation (7), one can see more clearly what modes are likely to play important parts in the configuration at any instant.

It should be stated that Ayre[1] first showed that the phase plane method can be applied to multi-degree-of-freedom systems. The present work, however, represents a slightly different approach showing that, by the immediate adoption of principal co-ordinates, the method is rendered very simple and easily applicable to a very wide range of problems indeed.

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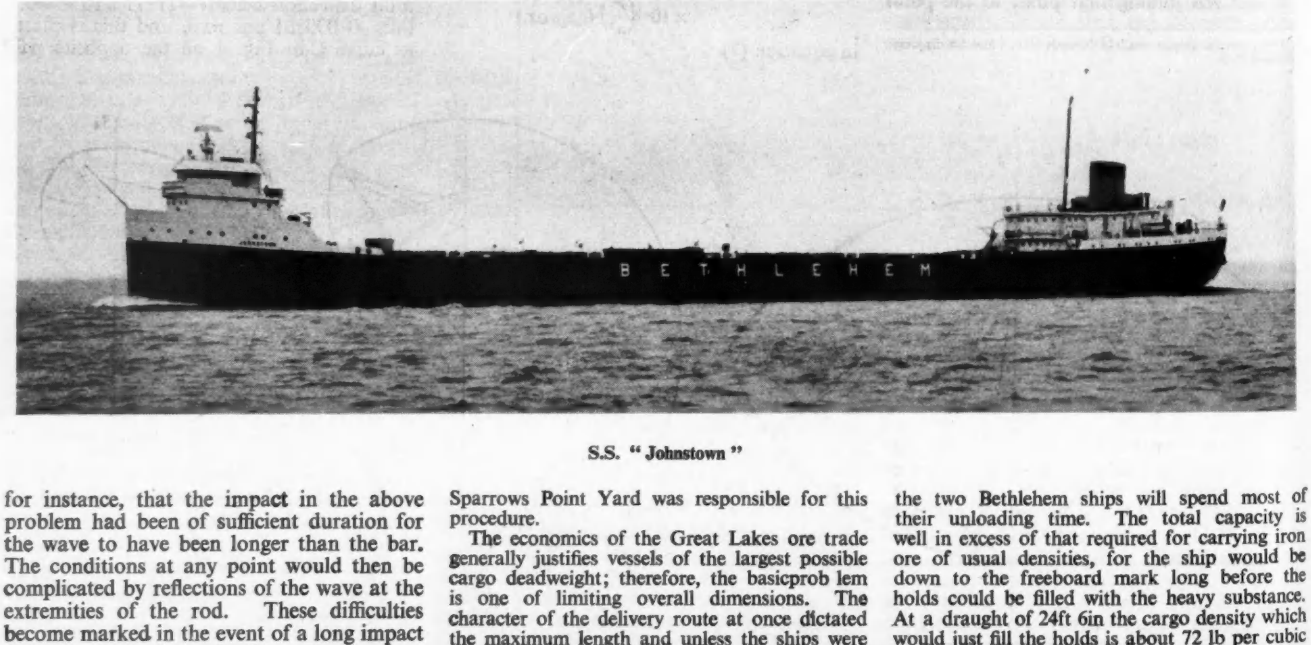
Large Ore Carriers for Great Lakes Service

(By Our American Correspondent)

The S.S. "Johnstown," "Sparrows Point" and "Elton Hoyt 2nd" were recently completed at the Sparrows Point Yard of the Bethlehem Steel Company in Maryland, U.S.A. The vessels are an example of the present trend in America toward large cargo deadweight capacities. On account of limiting clearances along the delivery route, including the Illinois Waterway and the Chicago Ship Canal, certain unusual problems were encountered in the design of these ships.

THE S.S. "Johnstown" and S.S. "Sparrows Point," owned by the Bethlehem Transportation Company, and the S.S. "Elton Hoyt 2nd," owned by the Interlake Steamship Company, were completed last year by the Bethlehem Steel Company at its Sparrows Point shipyard in Maryland. It is not common practice for American owners to place contracts for large Great Lakes ore carriers with yards not situated on the Great Lakes; but in this instance, the considerably better delivery obtainable from the Sparrows Point Yard was responsible for this procedure.

The economics of the Great Lakes ore trade generally justifies vessels of the largest possible cargo deadweight; therefore, the basicprob lem is one of limiting overall dimensions. The character of the delivery route at once dictated the maximum length and unless the ships were to be delivered in sections, an alternative which was considered but later discarded, the necessity of traversing the locks of the Illinois Waterway, particularly at Lockport, and the Chicago Sanitary and Ship Canal limited the overall length to not much over 620ft. Studies of clearances at the critical point along the delivery route indicated that a 70ft beam would be about the limit in association with the above length. The contour of the ore holds, the width of hatches and the position of the longitudinal bulkheads were determined largely by the unloading facilities at the Lackawanna steel works, where the two Bethlehem ships will spend most of their unloading time. The total capacity is well in excess of that required for carrying iron ore of usual densities, for the ship would be down to the freeboard mark long before the holds could be filled with the heavy substance. At a draught of 24ft 6in the cargo density which would just fill the holds is about 72 lb per cubic foot. The position of the cargo holds and the position of longitudinal centre of buoyancy



S.S. "Johnstown"

are such that even-keel trim is obtained when equal amounts of ore are loaded through each hatch.

With regard to propulsive power, the competitive disadvantage of the older and slower type of vessel is becoming increasingly evident in the Great Lakes service and it was therefore decided to install machinery of 7000 s.h.p. As well as driving the ship at a higher sustained speed, the additional power offers greater manœuvrability and the opportunity to make better speed through the heavy weather encountered early and late in the season. While oil is the basic fuel for these vessels, coal received serious consideration as a future possibility and definite provisions were made in the design for its use. If future economic conditions should favour the use of coal, the change over will be possible without a serious disturbance of the present arrangements. The following are the main characteristics :—

Length overall	626ft 1in
Length between perpendiculars	611ft
Breadth, moulded	70ft
Depth, moulded, to spar deck at side	37ft
Draught, moulded, designed	24ft 6in
Block coefficient	0·860
Prismatic coefficient	0·868
Midship section coefficient	0·991
At 24ft 6in moulded draught :	
Displacement, total, fresh water	24,745 tons
Deadweight, total	18,439 tons
Ore hold capacity	534,600 cubic feet
Fuel oil capacity	157,600 U.S. gallons
Fresh water capacity	129,300 U.S. gallons
Shaft horsepower, normal, at 115 r.p.m.	7,000
Sea speed, statute miles per hour	16

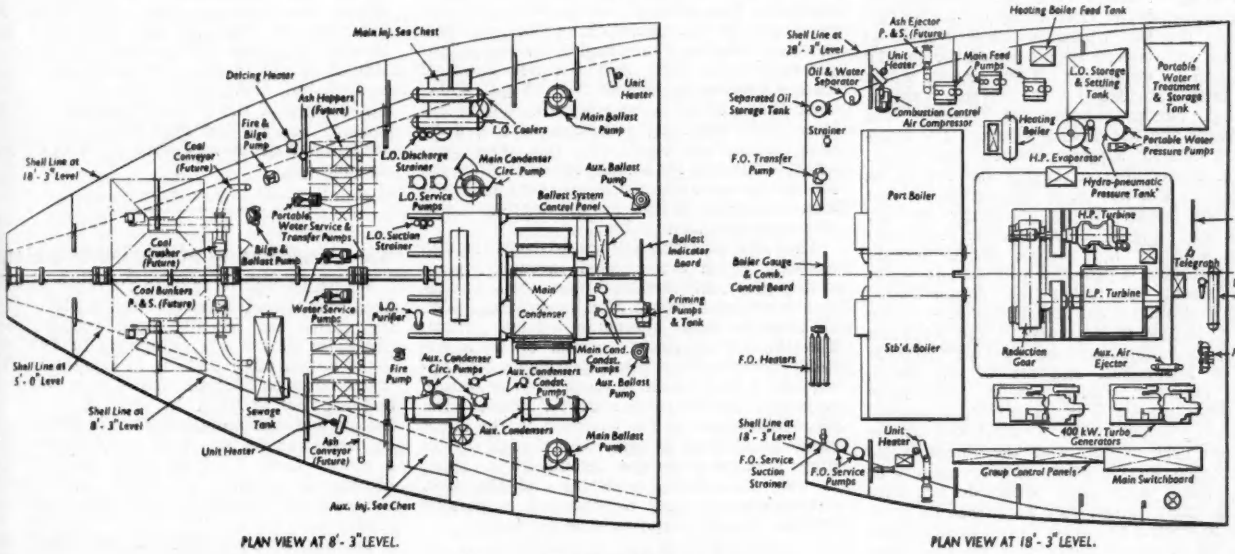
General Arrangement

Our illustration shows that in outboard appearance the vessels resemble closely the standard Great Lakes bulk freighter, with the crew ; owners' state rooms ; a hospital and the chart room and wheelhouse. A single stair well, centrally situated, provides the main access to all spaces. The deck houses at the after end provide accommodation for the engine-room crew and the engineer officers and also the mess rooms for all hands, galley, pantry and provision rooms, including refrigerated stores. The unusual position of the fuel oil bunkers and settling tanks is a result of the convertibility from oil to coal. If the change over is made, these tanks will serve as coal bunkers and are arranged for receiving coal from overhead storage bins.

The structural arrangements of these vessels are similar to those of Great Lakes ships now in service, but welding has been employed to a greater extent on these ships than on other large Lake vessels. Riveting was restricted on these vessels to certain deck and shell connections, mainly to act as crack arresters, and also in the superstructure to facilitate the erection and dismantling on the delivery trip.

The longitudinal passageway structure helped to balance the structural section of the main hull girder and made a contribution to the section modulus amidships. The inboard bulkhead of this passageway also protects the hatch coamings to some extent from the wear and tear of the unloading rigs. The twin longitudinal bulkheads are continued forward through the forward hold to the forepeak bulkhead and, at the after end, they are extended into the machinery space to form the inboard boundaries of the diesel oil and potable water side tanks.

The scantlings throughout the vessels were designed in accordance with the requirements of the American Bureau of Shipping and a



Machinery Arrangement

conventional grouping of deck houses on the forecastle and on the poop. There are four ore holds, which are separated by screen bulkheads, and are served by a total of eighteen hatches spaced 24ft apart. Access to and ventilation of the holds is facilitated by small watertight hatches in the spar deck with ladders below, so that all four corners of a hold may be reached without disturbing the main hatch covers. In addition there is one manhole to each hold, situated in a main hatch cover. The twin fore-and-aft passageways situated inboard of the longitudinal bulkheads provide unbroken and protected access between the machinery space and the forward quarters while preserving a high standard of water-tight integrity in the wings. The ballast tanks are divided into wing and centreline portions by the longitudinal bulkheads, unlike the usual arrangement where the tanks extend in one section from the wings to the centre line keel on each side.

The fore part of the ship below the spar deck is given over to a hold, tank spaces, stores and quarters for the seamen. Above the spar deck are the quarters for deck officers and

reduction in main scantlings was allowed because of the shorter length of waves on the Great Lakes resulting in lower bending moments in the ship girder. The stern frame is of cast steel, made in three pieces, with thermit-welded joints just above and just below the propeller boss, and the rudder is of double-plate construction. The absence of a fixed sternpost permits the propeller aperture to be enlarged by turning the rudder to one side and when turned 45 degrees, the tailshaft can be withdrawn aft a sufficient distance to facilitate the removal and replacement of stern tube bushings without disturbing the propeller hub.

In common with nearly all bulk carriers on the Great Lakes, the vessels have no effective water-tight subdivision in the centre-line cargo holds but a two-compartment standard exists abreast of the cargo holds, provided the longitudinal bulkhead remains intact, so that any adjacent pair of wing tanks may be opened to the sea without any more serious effect than causing a large angle of heel. The width of the wing ballast tanks is sufficient to protect the longitudinal bulkheads against any damage which is likely to be encountered in service.

The Sparrows Point yard has evolved a standardised system of ground assembly and erection which was applied, as far as possible, to these vessels and 81 per cent of the total weight of the hull steel was prefabricated, the sub-assemblies varying in weight from a few tons to 50 tons. The sub-assemblies were turned over during fabrication to permit a maximum of down-hand welding on all work and assembly jigs were used for such items as hatch covers and the screen bulkheads in the ore holds. About 476,000 linear feet of weld were deposited, of which 15,000ft were applied by machine and an electronic tracing device, working from black-and-white templates, was used largely to guide the oxy-acetylene cutting machines.

Machinery Installation

Since the owners required that, although the vessels were to be completed as oil burners, the arrangement of the hull structure and machinery were to be such that conversion from oil to coal firing could be accomplished expeditiously, it was decided that the structural and machinery arrangements would first be developed for a coal-fired installation. As shown in the accompanying drawing, the machinery was arranged with the propulsion unit forward of the boilers and the fuel oil tanks aft, thus permitting an acceptable arrangement of ballast pumps and piping at the forward end of the engine-room.

The forward bulkhead of the fuel oil tanks extends down to the inner bottom. The space below the fuel oil tanks, which would house coal conveying and crushing machinery if converted to coal firing, would therefore be separated from the boiler-room, and the bulkhead would tend to keep the boiler-room free of the coal dust associated with the conveying and crushing equipment. The machinery arrangement drawing indicates, in dot-and-dash lines, the changes necessary to convert the existing fuel oil tanks to coal bunkers, and the arrangement of the coal-handling equipment and induced draught fans when installed. The space that would be taken up by the ash hoppers and ash ejection equipment with coal-firing governed the position of the miscellaneous machinery items underneath the boilers.

Two Foster-Wheeler boilers are installed in each vessel. They are of the two-drum, bent-tube design and are equipped with side, rear and roof water walls, a convection superheater and an extended surface economiser. The boilers are designed to be converted readily from oil to coal, and sufficient grate area and furnace volume has been provided for this purpose. While the boiler front in way of the burners is designed so that it may be completely removed and replaced with three spreader stokers. The combustion air enters the boilers at the rear

and travels underneath the boiler and up the double front casing to the burners. Should it be necessary to convert from oil to coal, the boiler front would be removed and the boiler floor replaced with dumping grates; then the combustion air would discharge up through the grates to the furnace. The boilers have been designed to have a total evaporation of 30,000 lb per hour each, at a superheater outlet pressure of 450 lb per square inch gauge and a temperature of 750 deg. Fah.

The main propulsion unit, shown in the illustration on this page, consists of a h.p. and l.p. Bethlehem turbine connected in series; details of the turbine blading, speed and power distribution are given in the following table :—

Throttle steam conditions	435 lb per square inch gauge—740 deg. Fah.
Low pressure turbine inlet ...	28 lb per square inch gauge
Main condenser vacuum	28½in Hg
H.p. turbine :	
Type	Impulse-reaction
Shaft horsepower	3,700
Revolutions per minute ...	4,488
Number of stages	1 impulse, 22 reaction
L.p. turbine :	
Type	Reaction
Shaft horsepower	3,300
Revolutions per minute ...	2,311
Number of stages	25
Astern turbine :	
Type	Impulse
Number of stages	2

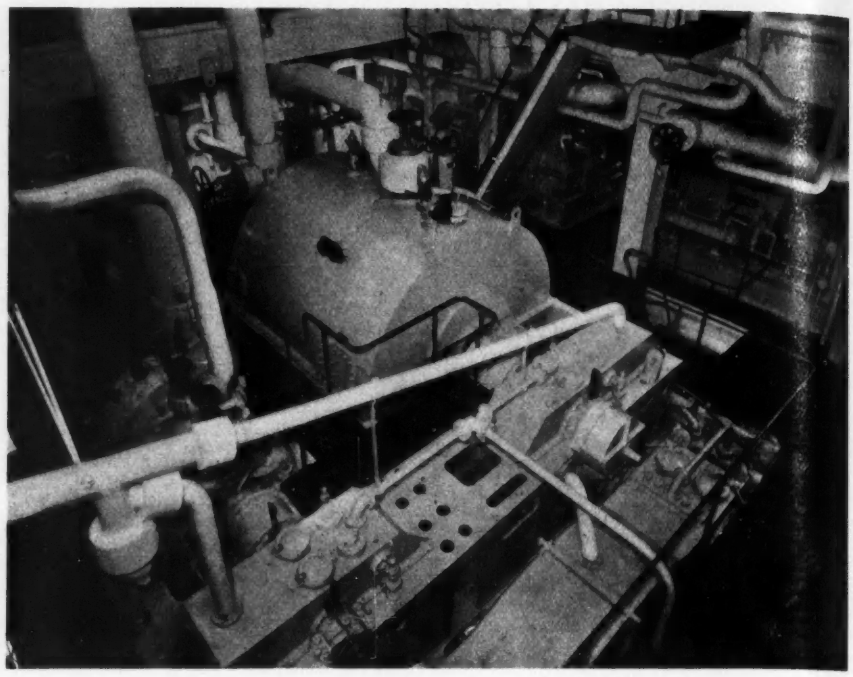
All blading is of stainless steel, the impulse blading being machined from solid bar stock and the reaction blading being manufactured by brazing together an assembly of rolled blades and packing sections. In the h.p. turbine, steam leakage around the reaction blade tips is minimised by channel-shaped monel metal shrouding with close radial clearances, and in the l.p. turbine the blade tips are thinned and operate with close radial clearances.

The h.p. turbine casing and the l.p. turbine inner casing are cast steel. A fabricated exhaust casing surrounds the inner casing of the l.p. turbine and provides a generous exhaust space to minimise any pressure drop between the blading outlet and the condenser. Three bleeder points have been provided on the turbine casings. The h.p. bleeder supplies the make-up feed evaporator and the heating system. The intermediate bleeder supplements the feed pump exhaust as required to supply the deaerating feed heater, and the l.p. bleeder serves the first stage feed heater. In an emergency the h.p. turbine can exhaust directly to the main condenser, with the l.p. turbine out of service. The l.p. turbine is provided with an emergency ahead steam line from the desuperheated auxiliary steam system for use in cases when the h.p. turbine is inoperative. The reduction gears were manufactured by the Falk Corporation, of Milwaukee, and are of articulated, double reduction, helical design. The main shaft thrust bearing is of the pivoted segmental type incorporated in the forward end of the reduction gear casing, with the thrust collar mounted on an extension of the main gear shaft. While many Lake vessels do not have propeller shaft sleeves, they were fitted on these vessels to protect the shaft from the salt water during the fitting-out period and the ocean part of the delivery journey. The propellers for these carriers were designed for the maximum power of 7700 s.h.p. at 119 r.p.m. and will operate at the normal power of 7000 s.h.p. at 115 r.p.m. They are of built-up, five-bladed design, and have an 18ft diameter and a 13ft pitch. The hub is of cast steel and the blades are of manganese bronze, finished to an aerofoil section, employing pitch reduction at the root sections. The blades are fastened to the hub with studs and nuts so that the pitch can be increased or decreased by about 1ft. Five blades instead of four were selected for the propeller design in order to minimise hull vibrations and to realise a possible gain in operating efficiency. Built-up propellers were chosen in the light of limited dry-docking facilities, limited time for repairs during the season, and frequency of blade damage. The usual Great Lake practice is to ballast the light ship down by the head to get the damaged propeller blade out of water. By this method, the old blade can be removed and a new one installed without dry docking becoming necessary.

Electrical Installation

For the primary power supply 450V, three-phase, 60 c/s a.c. was adopted with local transformers providing the 118V required for lighting and the 230V required for galley and pantry services. The variable voltage direct current necessary for the operation of six automatic mooring winches is obtained from two motor generator sets. The ship's service electrical load is supplied by two 400kW, 0·8 p.f., 450V, three-phase, 60 c/s turbo-generators, augmented by a 200kW diesel engine-driven generator of the same voltage characteristics. This latter unit, which is intended for standby service, is arranged to start automatically and to take over a selected load in the event of failure of the turbo-generator voltage on the main busbar.

The turbo-generator sets are driven by impulse turbines, which are coupled through gearing to drip-proof, self-ventilated generators. Excitation is obtained from a direct-connected 7½kW, 125V exciter with automatic voltage control. The standby generator consists of an eight-cylinder, four-cycle, supercharged engine developing 320 b.h.p., which is coupled to a 200kW generator similar to the 400kW units. The speed-load curve of the governor on the diesel engine is adjusted to agree with that of the oil relay governors on the turbine-driven units, so that the standby generator and the main turbo-generators may be operated in parallel for load transfer purposes when required.



Engine Room of S.S. "Johnstown"

Delivery

The following notes refer to the procedure adopted for the delivery of the S.S. "Johnstown" from the yard to South Chicago. The forward and after deck houses of the vessel were completely erected and all essential equipment was installed so that the vessel could function independently on trials. Lifting beams were integrated with the structure and the deck-house sides were slotted at the line of the break so that a minimum length of time would be required for their later removal and re-erection.

Calculations made in the early stages of the design gave no assurance that the hull could be ballasted safely to an even keel draught sufficiently light to negotiate the critical points on the delivery voyage, so a set of supplementary buoyancy pontoons was designed to achieve this object. Fenders were installed around the stern of the vessel, in order to prevent any over-riding of piling protecting the bridges along the route. They were kept clear of the water to eliminate drag and were designed to provide a pushing surface for the river towboats and to facilitate the attachment of the pontoons. The pontoons were not required for the delivery trip of the "Johnstown" since the water levels in the Mississippi were about normal at the time of transit, and without the drag of pontoons the voyage was relatively fast. The vessel left Baltimore on May 5th for the ocean tow, departed from New Orleans on the river tow on May 21st, and arrived at Lockport, Illinois, on June 4th. The transit of the numerous locks and bridges of the Illinois Waterway and the Chicago Sanitary and Ship Canal was without incident and the vessel arrived at South Chicago on June 6th.

Air Conditioning at Shell-Mex House

We paid a visit recently to the boiler-room of Shell-Mex House, where the heating and ventilating plant has recently been reconditioned. Shell-Mex House was completed in 1933 and is the largest office building in London. It has fifteen floors on the Embankment side, where the building rises to 201ft. In spite of its age, the heating and ventilating equipment installed is still believed to be the one of the more efficient in the country. Over 8,000,000 cubic feet of space heating is involved for which 1475 heating radiators and 22 miles of water piping have been installed.

There are six Davey and Paxman "Economic" forced draught boilers served by a common induced draught fan at the main flue.

Four of these boilers provide steam at 50 lb per square inch to four heating calorifiers, each rated at 3,750,000 B.Th.U. per hour, from which water at 180 deg. Fah. is pumped to the heating circuits at the rate of 900 gallons per minute. The temperature is controlled by modulating valves and the return temperature is 160 deg. Fah. Separate calorifiers are used to provide hot water for the kitchen and domestic supplies. Steam from the calorifiers passes to a condensate return tank from which feed water is pumped via preheaters to the boilers.

An ammonia refrigerating plant which operates in conjunction with ventilating plant for air conditioning of the restaurant, is housed adjacent to the boiler-room. It is capable of eliminating 1,500,000 B.Th.U. per hour. The air-conditioning plant can supply 25,000 cubic feet of washed air per minute and the restaurant air is changed completely four times an hour. The air temperature is automatically controlled by steam heaters. An air-conditioning plant of similar capacity is provided for the kitchen. Clean air which is warmed in winter is supplied to the rest of the building from five ventilating plants in the clock tower and the central tower.

Mechanical Engineering Research

LAST week there was published the report of the Mechanical Engineering Research Board, of which Sir Andrew McCance is now chairman in succession to Sir Henry Guy, for the year 1952. It will be recalled that the Mechanical Engineering Research Laboratories are at East Kilbride in Scotland and that much staff and equipment has been in process of transference to that new laboratory since it was set up. The document* includes the report of the director of mechanical engineering research, Dr. D. G. Sopwith. Below we reprint abstracts from the report of the Board.

Early in the year the remainder of the staff and equipment of the Mechanisms and Metrology Division were transferred from the National Physical Laboratory, Teddington. They were accommodated in such space as could be made available for them in the workshop and staff restaurant at East Kilbride. The heavy mechanisms section of the Division was already established in temporary premises at Thorntonhall, about 4 miles from East Kilbride. The team working on the mechanical properties of materials at high temperatures (creep) must remain at the National Physical Laboratory until money can be made available for the erection of a suitable building at East Kilbride, but the research on creep under combined stress is now being carried out in Scotland as part of the work of the Materials Division. The team in the Heat Division engaged on the preparation of thermodynamic tables was transferred to Scotland at the end of the year.

In our report for 1951 we referred to the work which is being undertaken in universities under research contracts on our programme. With one exception these are being continued and are referred to in Appendix I of the Director's Report. The exception is the investigation on helical torsion springs carried out at Leeds University ; this work has been completed and a paper has been prepared for publication.

The building programme at East Kilbride has been severely affected by the Government's decision to restrict capital expenditure. Construction of the hydraulic machinery laboratory began in May and will take about two years, but a start on the heat transfer laboratory has once again had to be deferred. The available accommodation at East Kilbride and Thorntonhall is becoming more and more congested. Urgent consideration is being given to the possibility of acquiring temporary accommodation in the neighbourhood, but so far no success has been achieved. The greatest handicap to the further progress of our investigations is the lack of adequate laboratory space.

Our annual visit to the Laboratory took place in June and we were impressed by the speed with which the transfer of existing equipment and the installation of new equipment had been effected. We were pleased to have with us on that occasion the Secretary of the Department, Sir Ben Lockspeiser, K.C.B., M.I.Mech.E., F.R.S.

We appreciated the authority given during the year for the addition to the staff of thirty non-industrial members and for some addition to the industrial staff. Recruitment to fill the new posts has gone on steadily, but it has proved difficult to fill the more senior posts ; two posts at Principal Scientific Officer level remain unfilled.

We are glad to record that no housing difficulties have hampered development. The East Kilbride Development Corporation has been able to provide houses for the staff transferred from England and those recruited from a distance in a comparatively short time.

Close relations have been developed with the University of Glasgow and the Royal Technical College, Glasgow. The Principals of both institutions, Sir Hector Hetherington, K.B.E., and Dr. David S. Anderson, and the engineering professors have visited the laboratories and there is a useful interchange of ideas between the University and College staff and the staff of the Laboratory on the research work in progress. There is also marked evidence of the interest which local industry is taking in the enterprise.

The research in progress is described in the Director's report. We confine our comments on it to the main features of the work of the three Divisions on which we had a special report during the year.

Lubrication and Wear Division.—Sir Geoffrey Taylor predicted, that, in a cylinder rotating coaxially in a stationary cylinder, vortices would begin to form in a liquid in the annular space at a certain value of a non-dimensional parameter embracing speed, viscosity and clearance. With the present tendency towards higher speeds this critical value may be reached in bearings. Taylor's prediction has been investigated experimentally in the Lubrication and Wear Division, and the fact that a loaded bearing operates eccentrically has been taken into account. It has been shown that eccentricity raises the value of the non-dimensional parameter governing vortex formation and that designers are therefore unlikely to encounter difficulties due to the breakdown of laminar flow provided they do not permit Taylor's parameter to be exceeded.

The work on thrust bearings, both of the plain and tilting-pad types, at speeds up to 16,000 r.p.m., using air gauging, has been continued. It is hoped that work on journal bearings, including the use of a capacitance method of measuring attitude and eccentricity, will provide information on bearing design and oil requirement. In view of the need for information for designing gas turbines, the construction of new machines which will run at speeds of at least 50,000 r.p.m. is under consideration. The requirements of gas turbines have also been responsible for concentration on the study of the behaviour of roller bearings at relatively high temperatures (250 deg. Cent.).

The main interest in the field of boundary lubrication has shifted from the lubricant to the surface coating and a study has been made of the effect on frictional behaviour of anodised films on aluminium. The Division has shown that, by anodising a suitable aluminium alloy and providing the correct lubricant, this normally troublesome material may be made to operate satisfactorily when rubbing against steel. Some fundamental research on grease lubrication has led to a tentative bearing theory to take into account the rheological properties of grease. Among the furthest advanced items of research in the Division is the work on fretting corrosion, which will form the subject of a paper to the Institution of Mechanical Engineers. The experiments have placed the subject on a quantitative footing and it has been confirmed that phosphated steel surfaces are very resistant to fretting corrosion and that its occurrence on surfaces so treated can be virtually eliminated by suitable lubrication. The role of moisture in the phenomenon is being studied, and a preliminary conclusion is that fretting corrosion is more severe at high and low humidities than it is under normal conditions.

The so-called Kramer effect, in which it is suggested that there can be an electron emission from worked surfaces, is being studied. An understanding of the phenomenon will probably be useful in the study of the fundamentals of wear and in other fields, including the fatigue strength of materials. The work is at a very early stage, but has already led to a tentative hypothesis that the effect is not due to direct emission of electrons, but to charged ions arising from the process of oxidation.

Mechanics and Materials Divisions.—Fatigue of metals is one of the major items in the programme of the Materials Divisions. In the work at air temperature the results of direct-stress fatigue tests on a mild steel, a heat-treated alloy steel, and an aluminium alloy in sheet form have been published. This was the first detailed programme for which the 60-ton direct-stress Schenck machines were used. The work showed that the marked difference between the strength-reduction factors usually associated with mild steel and heat-treated alloy steel respectively tends to disappear as the size of the part increases, and it is considered that the results emphasise the importance in all fatigue tests of the actual stress distribution at the point of failure. Special interest attaches to the results obtained in fatigue determination on a certain type of aircraft pin joint, known to give trouble in service ; these showed that the very low fatigue strength, and consequent poor service performance, was due to fretting corrosion between the pin and the hole in the tongue.

Fatigue is also one of the aspects of the other major item—high-temperature materials—but much attention is also being directed to the effect of combined stress. The effect of cyclic speed in alternating stress tests at high temperatures has been studied on mild steel and on an aluminium alloy. Fatigue tests in alternating bending and in direct stress usually give different results ; it has been shown that if nominal stresses are corrected to true stresses on the basis of the dynamic stress-strain curve the differences can be reconciled, at least in the materials tested.

A comprehensive investigation is being made of the relations between stress, creep strain, plastic strain, time, and temperature of a number of high-temperature alloys under combined stress systems ; preliminary work on some alloys has indicated the probable form of these relations for general loading conditions. The effect on creep of periods of peak stress and varying temperature, such as occur in power station practice, has been examined.

The limited staff available has restricted the work on stress analysis but a certain amount of theoretical work has been undertaken. Arising from a number of failures in service, the cylinders of a series of industrial presses were examined on site by means of wire resistance strain gauges to determine the stress distribution occurring during pressing operations.

A good deal of time is spent on investigations for industrial firms, including investigation into failures of such things as a large crankshaft, vehicle chassis and engine components, gas cylinders, and turbine blades.

Mechanisms and Metrology Division.—This Division was the third to report to the Board during the year. Short-term tests and special investigations for industrial firms and for the Admiralty and Ministry of Supply also occupy a good deal of its time. At the end of the year thirty were in hand, a large proportion of them being associated with the naval shipbuilding programme. The work of the Division is divided into three sections : engineering metrology, instrumentation and servo-mechanisms, and heavy mechanisms. In the metrology section investigations are being made into the performance of fine-pitch gears for precision instrument and clockwork mechanisms by recording the relative change in angular velocity of a gear pair when operating under normal service conditions. The work includes an analysis of spur gears produced by different machining processes, and the results indicate that while shaving reduces the profile errors it does not appreciably modify the cumulative division errors. They also indicate that there is room for improvement in the accuracy of manufacture. With the trend towards much harder materials and heavier tooth loads in marine gears there was a need for further refining in methods of measurement. A portable recording instrument has been designed and a prototype made in the Laboratory for inspecting large helical gears. With the expansion of the defence programme the Laboratory has received an increasing number of requests to examine marine gear cutting hobs and shaving cutters; arrangements are now being made for the manufacturers to issue their own test reports of accuracy based on mutually agreed test specifications.

A paper has been published describing a new and relatively inexpensive portable measuring head and pneumatic comparator for gauging the surface finish of both flat and cylindrical surfaces. The instrument can be applied directly to the machine tool. In the instrumentation and servo-mechanisms section a high-speed testing rig is being designed and developed for assessing the overall performance of small high-precision ball bearings at speeds up to 100,000 r.p.m. under conditions of combined axial and radial loads. An experimental air bearing with a 1in

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* H.M. Stationery Office. Price 2s. 6d.

bore has been constructed to gain experience in running high-speed spindles and bearings. A prototype bearing has been run successfully up to 40,000 r.p.m. Automatic measuring devices are being developed in which the errors can be displayed by chart recording mechanisms. One example of particular importance is an apparatus for measuring spacing errors in master gears and precision index plates.

In the heavy mechanisms section facilities are now available for the design, manufacture, inspection and load testing of spur and helical gear drives. The work in hand includes an investigation to determine the relative merits of shaved and hob-cut gears, using power circulators of the back-to-back type. Shaving is a relatively new technique in this country and there is little reliable information available on the design of the cutter profile, the optimum crossed-axis angle, and the most suitable speeds and feeds to use. Experience has shown that it is possible to "over-shave" a gear, which tends to work-harden the tooth surface and may result in early failure of the gear in service.

The Operating Range of Electronic Flame Failure Devices

THE North Thames Gas Board has investigated the useful operating range of a number of electronic flame failure devices which function by virtue of the electrical resistance of a flame. The results of this work were submitted to the Gas Development Committee of the Gas Council, 1, Grosvenor Place, London, S.W.1, and they are incorporated in a report (No. 515/52), the substance of which is reproduced herewith.

The operating range of the electronic flame failure devices was determined by connecting resistances between the electrode and earth, and varying the value until the relay cut in. Two resistance ranges are necessary for this purpose, one for the upper limit and one for the lower. Each range must be capable of a wide variation since tests have shown that the upper limit may fall between 90 and 250 megohms and the lower between 80,000 and 500,000 ohms, according to the make of the control equipment.

Numerous fixed resistances were obtained having values between 10,000 ohms and 10 megohms. Ten 10 megohm resistances were coupled in series to give a fixed resistance of 100 megohms and 15 were soldered to a multi-stud switch to enable the resistance to be varied in 10 megohm stages. The remainder were connected in series, with tapping points between each. For the determination of the upper limit, the megohm and 1/10 megohm resistances only were used. For the lower limit the 10,000 ohm resistances were used in conjunction with a Post Office box.

The method of obtaining the upper limit was to set the resistance to a value exceeding the upper limit and to reduce it until the relay switch changed over; the reading was then taken. The value was increased until the relay cut out again; this value was also recorded; two values for the upper limit were thus obtained, one being the maximum flame resistance at which the relay holds in, the other being the maximum at which the control cuts in. Similarly,

Effect of Voltage on Relay Operating Range

Supply voltage	Upper limit		Lower limit	
	Energised megohms	De-energised megohms	Energised megohms	De-energised megohms
200	150	167·5	0·42	0·38
190	147·5	167·5	0·46	0·38
180	137·5	158·9	0·47	0·41
170	120	141	0·49	0·42

for the lower range, the value of the resistance was increased until the relay cut in and then reduced until it fell out. Both resistance values were recorded. By this method, two operating limits were obtainable for each device, one being the limits between which the relay would hold in, the other the limits between which the relay would automatically cut in.

It was found that once in operation, the electronic controls operate over a much wider range. The effect of voltage variations was also determined and the results obtained on one device are tabulated above.

From these figures it became apparent that all controls should be tested at the same voltage in order to obtain comparative results. In the tests described, to eliminate difficulties experienced in obtaining the nominal single-phase a.c. voltage, a value of 200V was selected.

At this value, tests on three different types of control gave the following results :—

Relay Operating Range for Three Typical Equipments

Model	Upper limit		Lower limit	
	Energised megohms	De-energised megohms	Energised megohms	De-energised megohms
1	224	254	0·35	0·32
2	100	170	0·09	0·05
3	149	161·8	0·38	0·35

The above figures show that the operating range of electronic flame failure devices tested, is considerably greater than has been previously quoted. The list of devices tested is not yet complete, and in placing the figures on record it must be stressed that it is not possible, without considering all the operating conditions of the plant to which the electronic flame failure device is fitted, to decide on the advantages or disadvantages of any particular working range of electrical resistances.

It is desirable for the lower operating limit to be high enough to ensure reasonable immunity from accidental operation by leakage resistance. Such an artificially imposed leakage might be created, for instance, by the flame electrode touching damp brickwork, or by an operator being in a position to touch the electrode and hold it lightly.

The problem is eliminated entirely if a flame failure device can be associated with a circuit which ensures that it is impossible to start up if there is a leak in existence. In the absence of such a circuit, however, it is not easy to reduce the lower operating limit without bringing about a corresponding reduction on the upper operating limit. Since these devices, in general, have to operate with a wide range of gases having different characteristics, the possible expense of making such equipment to reduce the lower operating limit only for one particular type of gas may not be justified, but as the resistance of the human body is of the order of 50,000 ohms, it may be desirable in any case to raise the lower operating limit to 0·5 megohms.

The International Civil Aviation Organisation Assembly at Brighton

A FULL-SCALE session of the Assembly of the International Civil Aviation Organisation was held in Brighton, Sussex, from June 16 to July 6, 1953. The main task of this session, the seventh since I.C.A.O. was formed in 1947, was to review the work of the organisation in the administrative, economic and technical fields during the past three years and to provide the twenty-one-member council and its subsidiary bodies with policy decisions for the future.

Air Transport.—In the economic field the Assembly was chiefly concerned with the international operating rights of airlines and other operators of air transport services. Since the decision of all states that each must retain sovereignty over its own air space, and cannot permit nationals of other countries to operate air services into its territory without permission, repeated attempts have been made to devise some general form of permission to be agreed upon by all nations, so that operators of international services could arrange them to the best possible advantage without the necessity for constant reference to governments for permits and licences. It has proved impossible, however, to evolve a formula acceptable to all states, and the network of international air services now covering the world is the result of some 300 special agreements between various pairs of governments. Those agreements have tended to sectionalise the world and to make air transport both more expensive and less convenient than it should be.

This matter of operating rights was thoroughly studied and discussed in Brighton. The conclusion reached was that the time was not yet ripe for attempting world-wide agreement concerning the exchange of commercial rights in international air services. The possibility of some form of regional agreement has been raised by the Council of Europe, which wishes to see the unification of Europe extended to the air. The Council of Europe has requested I.C.A.O., as the international body concerned with all aviation problems, to convene a conference to consider various measures to co-ordinate and improve European air transport. This proposal has been approved by the I.C.A.O. Assembly and preparations for the conference will shortly be made. Meeting immediately after the Assembly, the council decided that a preparatory committee composed of representatives of Belgium, Denmark, France, Italy, Netherlands, Norway, Sweden, Switzerland and the United Kingdom should meet in October, 1953.

The Assembly also gave special attention to the needs of non-scheduled international air services. It was felt that it was too early to expect universal freedom for this type of transportation, but it was agreed that the I.C.A.O. Council should explore this matter to see how charter operations could be distinguished from regular services, and which charter operations could be given general freedom of operation internationally, without encroaching on traffic of the regular services.

The problem of the growing cost of airports and radio facilities for air navigation was also discussed. The airlines could not bear the whole cost of these services without an excessive increase in passenger fares, which would result in a decrease in traffic. In view of the fact that different states are not in agreement as to what sort of charges would represent a reasonable balance between the operators of airlines and the operators of airports, it was agreed that the council should issue a purely factual report on the situation, so that governments could examine it independently and reach their own conclusions.

Air Navigation.—The Assembly decided that the moment had arrived when more emphasis could be placed on the implementation of international standards, practices and procedures. In general, the I.C.A.O. international standards are framed in such a way that little difficulty is experienced in implementing them. An exception exists, however, in the international standards for airworthiness. At present the I.C.A.O. airworthiness standards cover only three categories of aircraft and the standards are mandatory only in so far as they concern aircraft which have been voluntarily certified as conforming with the specifications relating to one of the three categories. For this reason there is no obligation on the part of a particular state to conform exactly to the requirements or to notify the organisation of departures therefrom. However, not only have the airworthiness standards proved a valuable guide to aircraft manufacturing states, but, in accordance with the Convention on International Civil Aviation to which each I.C.A.O. member nation is a party, every aircraft flying an international air route must possess a certificate of airworthiness issued by the state in which the aircraft is registered. The aircraft manufacturing countries of the world see to it in their national regulations that any such aircraft, and indeed all other aircraft produced by them, are fully airworthy. Nevertheless, it would be desirable for international airworthiness standards to exist to which all aircraft would have to conform. Such standards would naturally have to be limited to broad principles of safety and airworthiness, for otherwise initiative in the design and performance of aircraft, on which progress depends, would be stifled. The advent of the jet has emphasised the desirability of some action being taken by I.C.A.O. to develop international airworthiness requirements to which all aircraft-producing states would have to conform. The Assembly in Brighton was of the opinion that it was highly desirable to arrive at a solution at the earliest possible date, and it adopted a resolution which would strengthen the hand of the council in the work already undertaken on that question.

Commonwealth Cable Conference

A COMMONWEALTH conference on cable standards was held, under the chairmanship of Mr. P. V. Hunter, at the Victoria Street, London, headquarters of the British Standards Institution from July 14 to 22, 1953. It was attended by representatives from the national standards organisations of Australia, India, New Zealand, Pakistan and the United Kingdom. Observers from Ceylon and the Union of South Africa were also present. The primary object of the conference was to achieve a better understanding of the different points of view held in the Commonwealth countries on standards for rubber-insulated, paper-insulated and P.V.C.-insulated cables, and to endeavour to make recommendations for subsequent consideration by the standards bodies in the Commonwealth, with the object of securing the greatest possible uniformity in future standards for cables. Representatives attending the conference were not empowered to make decisions which would commit the various national committees on any principle or detail. The discussions will be referred back to the respective national committees for consideration, and it is hoped that further conferences of a similar nature will take place from time to time.

The conference agreed in principle on the desirability of the standards for cables in the Commonwealth countries being as nearly as possible the same. It was appreciated that in some countries the standards had statutory significance, and hence cables and flexible cords which did not comply with the standards could not legally be used or sold in those countries. It was also recognised that the form in which the standards were drafted was to some extent of existing standards in those countries could not determined by similar considerations. A revision therefore be made without full consideration of the statutory implications involved.

Among the more important recommendations requiring special consideration by the national committees are the following.

RUBBER-INSULATED CABLES

Composition of Rubber Insulation.—Owing to the differing views expressed regarding the advisability of specifying the composition of the rubber insulation instead of relying entirely on test requirements to assess its quality, it was recommended that all Commonwealth countries should reconsider this matter. In the event of their deciding in favour of specifying the composition, consideration should be given to the views expressed at the conference regarding the advantages of a low volumetric limit of rubber content. Consideration should also be given to the desirability of specifying two separate grades of compound for use respectively, in temperate climates and in tropical climates.

Method of Measuring Insulation Thickness.—The conference had its attention called to a proposal, which had received support in the United Kingdom, that the thickness of insulation should be expressed only in terms of a minimum value, without reference to the average value. It was noted that in all Commonwealth countries the insulation thickness is at present expressed in terms of a minimum average value, associated with an absolute minimum at any point, and the conference recommended that this method of expressing thickness be retained.

Voltage Classification.—The conference recommended that rubber-insulated cables should be classified into medium-voltage, general-purpose cables, and medium-voltage, heavy-duty cables as follows. Medium-voltage, general-purpose cables are those which are suitable for use on any system where the voltage to earth does not exceed 400, and on any three-phase system with earthed neutral point in which the voltage between conductors does not exceed 690. Medium-voltage, heavy-duty cables are those suitable for operation at 660V to earth, and on any three-phase system with earthed neutral point in which the voltage between conductors does not exceed 1100.

Insulation Thickness.—The Commonwealth standards bodies are to be requested to consider the possibility of adopting thicknesses for the general-purpose, medium-voltage cables equal to 85 per cent of the thicknesses specified in B.S. 7 : 1946 for 250V cables, subject to a minimum insulation thickness of 0·030in. It was recommended that the figures so determined should be specified to the nearest mil in order to provide a more logical system of increasing insulation thickness with conductor size.

Flexible Cords.—It was recommended that the standards bodies should consider adopting flexible cords with the proposed modified "standard" (or "nominal") thickness of insulation for all purposes, since the special cords with reduced thickness of insulation previously intended for vacuum cleaners, pendant lighting fittings and the like are now regarded as redundant.

PAPER-INSULATED CABLES

Core Identification.—It was proposed that factory lengths of cable should have their ends labelled "A" and "Z" respectively, the "A" end having cores numbered in a clockwise sequence and the "Z" end having the cores numbered in an anti-clockwise sequence. To identify low-voltage (1100V) cables a perforated paper tape was recommended for inclusion over the sheath.

Bedding, Armouring and Serving.—The same dimensions of bedding, armouring and serving were recommended for adoption for both rubber-insulated cables and paper-insulated cables, and a recommendation was made regarding a specification for the compounds used in beddings and servings.

P.V.C.-INSULATED CABLES

Voltage Classification.—The conference proposed that P.V.C.-insulated cables should be classified into medium-voltage, general-purpose and medium-voltage, heavy-duty grades as for rubber-insulated cables.

Insulation and Sheath Thickness.—It was recommended that the Indian and United Kingdom national committees should consider reducing the dimensions of the single-core unsheathed P.V.C. cable so as to correspond with the single-core, rubber-insulated cable, and that the Australian Committee should consider adopting a range of thicknesses of P.V.C. insulation and sheath on the same basis as those for rubber cables.

Composition of P.V.C. Insulation.—It was recommended that the Commonwealth standards bodies committees should review the question of either specifying the limit of vinyl chloride content in the polymer, or specifying mechanical tests on the extruded P.V.C. compound.

Tests.—It was recommended that insulation resistance figures should be based on a resistivity value of 2×10^{13} ohm-cm.

In view of the opinions expressed regarding the adoption of loss in weight or depreciation in tension strength as the most appropriate test criterion, it was agreed that this matter should be further studied to determine the factor most indicative of service behaviour.

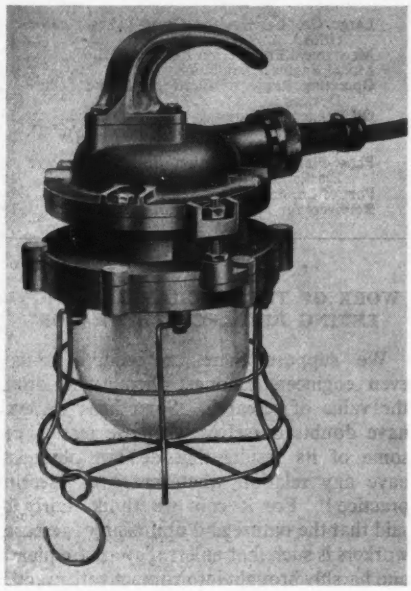
Although various tests for determining resistance to fire, abrasion, &c., have been formulated, it was felt that further information should be obtained as to how far these properties are inherent to P.V.C. compounds and, therefore, require governing tests, and to what extent physical performance is controlled by tests on the more fundamental properties.

A Flameproof Handlamp

THE flameproof handlamp illustrated herewith has been introduced by Simplex Electric Company, Ltd., of Broadwell, Oldbury, Birmingham, for use in dangerous atmospheres. It is said to be the first handlamp to carry a Buxton certificate for full "flameproofness." This 40/60W handlamp, designated F8080, is covered by the Ministry of Fuel and Power certificates, Flameproof No. 3139, for Groups II and III gases. It has been designed specifically for use with a particular kind of screened cable, which is described below, and it can be used in conjunction with the Simplex flameproof (Buxton certified) interlocking switch socket and plug.

The handlamp is made of aluminium alloy and consists of three parts, a terminal box with cable gland and handle; a body portion with lampholder and terminals; and a well glass with a guard and ring.

The connection box and top face of the handlamp body are flanged in the normal way and are joined by four shrouded bolts. The well glass ring has a spigoted portion which is assembled to the handlamp body. An important aspect of the design is that only two studs and nuts are used to secure these two portions together and the two nuts are the only fastenings that have to be removed before the well glass is detached for re-lamping. A spigot joint ensures that a flameproof path is maintained irrespective of the tightness of those two nuts. The lampholder (B.C. or E.S.) is of porcelain with permanent heat-resisting connections to the stem terminals. For the well glass type "A" glasses are cemented into the dual well glass (B.S.S. 889 : 1947) rings. A stout galvanised wire guard is supplied as



Flameproof Handlamp

standard. It is so designed that a straight edge in any position cannot make contact with the glass, and it incorporates a hook so that the handlamp can be suspended. Alternatively the fitting will hang from the handle when hooked over a bar.

The gland consists of an anti-kink polychloroprene muff and a polychloroprene packing washer, which is compressed in the usual way. The gland will only accommodate cables which have an outside diameter varying between 0·46in and 0·5in. In the terminal chamber there is ample wiring room with the following facilities: two terminals for the live conductors, which are fitted with mechanical clamps secured by screws and washers; an internal boss which is fitted with a screw and Ross-Courtney type of terminal for the earthing conductor; a mechanical clamp for the cable screening; a clamp for anchoring the strengthening cords of the cable.

The handlamp has been designed for use with a cable specified as follows: three-core, 23/0·0076 tinned copper insulated with vulcanised rubber to B.S.S. 7–250V grade; cores to be laid up with strengthening cords in the interstices and insulated with further layer of vulcanised rubber or polychloroprene (neoprene); tinned copper braid screen with strands not exceeding 0·012in and enclosed overall in a heavy-duty polychloroprene (neoprene) sheath not less than 0·05in thick; overall diameter 0·046in to 0·05in.

The equipment described here is suitable for use with all voltages up to 250V to earth.

KWINANA JETTY.—At the Kwinana refinery being built near Fremantle, Western Australia, for the Anglo-Iranian Oil Company, Ltd., the first steel piles have been driven in the construction of the permanent jetty which will have an arm 1000ft long running at right angles to the shore and a sea arm 1700ft in length.

THE ENGINEER

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WORK OF THE MECHANICAL ENGINEERING RESEARCH LABORATORY

We suppose there are people to-day, even engineers amongst them, who doubt the value of research. Sometimes we even have doubts ourselves when we read about some of its results that do not obviously have any relation whatever to engineering practice! For it can, we think, fairly be said that the nature and optimism of research workers is such that unless they are frequently and harshly brought into contact with practice much of their work becomes useless in the engineering sense, whatever its value may ultimately be to science. No one, however, reading the report, issued last week, of the Mechanical Engineering Research Board for 1952, is likely to have the least doubt about the value of the work being done at East Kilbride. It has, for example, been estimated that 90 per cent of the failures of high-speed machinery are the consequences of the development of fatigue. The fundamental physical nature of the phenomenon is not fully understood. But investigation of that rather fundamental matter is not taken to be the responsibility of the laboratory. Work upon it has been started at Bristol University under contract from the laboratory. A more directly practical investigation for the detection of fatigue has engaged the attention of the laboratory itself. Again it has been observed that though hydraulic control valves are used in many industries little is known about their behaviour and the flow patterns inside them. Research into such a subject has an obvious practical usefulness. Once more, lubrication plays a fundamental part in the adequate working of machines. Yet the laboratory has found that there is comparatively little known about the behaviour of grease in ball and roller bearings and that the action of grease in a bearing does not well accord with the supposition that it acts as a reservoir for oil, steadily exuding small amounts. Many another example, could be quoted from the report, abstracts from which are printed on page 173, of work now being undertaken for obviously practical purposes. It is, indeed, rather astonishing to find how many apparently simple matters affecting the operation of mechanical machinery have never before been adequately investigated.

When we turn, however, from a study of what the laboratory is doing to a consideration of the speed with which its buildings and equipment are being built up a much less satisfactory situation is seen to emerge. The report shows not only that there is congestion at East Kilbride owing to lack of space to carry out research but that the progress of the work is being badly impeded by the Government's decision to restrict capital expenditure. Though construction of a hydraulic machinery laboratory was begun in May, 1952, it will take two years to complete; and a start on the much needed heat transfer laboratory had wholly to be deferred. Nowhere than at East Kilbride is the short-sightedness of that Government policy more obviously demonstrated. Again and again in reading about the work of research bodies we learn how it is being held up by lack of finance. Certainly we think it no bad thing that research workers should not have money too freely available. Shortage of cash is a great encouragement to the use of ingenuity in devising methods of experimenting effectively as well as cheaply and to the use of brains in determining, before experiments are undertaken, whether they will really serve a useful and positive purpose. But research bodies should not be subjected annually and unpredictably to variations in income. They ought to be able, as surely as universities are under the system of quinquennial grants distributed under the ægis of the University Grants Committee, to plan ahead for new buildings, new researches and new equipment. Though over the country as a whole restriction of capital expenditure proved unquestionably necessary in 1952, we feel that it should have been applied with greater discretion. Come boom, come slump, research should be carried on as smoothly and regularly as possible.

Another point of some interest emerging from a study of the report is the fact that difficulty is being found in finding people to fill senior posts. It illustrates once again that there is still a shortage in this country of adequately trained engineers. Some of the difficulty arises, as the University Grants Committee pointed out in a report we recently reviewed, because in the minds of parents and perhaps schoolmasters, too, pure science and the arts enjoy a prestige superior to that of technology so that the latter does not attract the proportion of brighter young men that is its due. Only time will bring about a change of heart. Yet the change may well be hastened by the very gratifying interest H.R.H. the Duke of Edinburgh has been showing for many months past in the technological work of universities and research establishments. And, while we are thus writing of universities it is encouraging to learn how rapidly the laboratory has established what are clearly quite intimate relationships with the staffs of Glasgow University and the Royal Technical College. A really fruitful collaboration may result. In conclusion, too, all those who know what high service to the development of the Mechanical Engineering Research Laboratory was rendered by Sir Henry Guy will welcome the acknowledgment made of them in the report.

ROAD SAFETY AND ROAD EXPENDITURE

It is not altogether surprising that the citizens of other nations sometimes think the British mad, perfidious and hypocritical. In an excellent debate that took place last week in the House of Commons on traffic congestion and road accidents, Mr. Lennox-Boyd, Minister of Transport, was the spokesman of a Government which, since it came to power, has consistently followed the practice of its predecessor in starving the roads of sufficient money for satisfactory maintenance, let alone improvement. Yet, paradoxically enough, his statement would have come more appropriately from a Minister justifying heavily increased expenditure upon the roads than from one excusing the expenditure of so little! He referred, for example, to the rate of increase in the number of vehicles on the roads and mentioned an estimate that by 1965 they will number over 6,000,000 compared with under 5,000,000 to-day; to the estimate that "£150 million a year is what we lose in injury and accident alone"; to the millions of pounds worth of works started but not finished, such as the Purfleet Tunnel; to the proportion of accidents occurring in built-up areas amounting to nearly 80 per cent of the whole, some of which (it is our remark, not his) could be prevented were motorways built to by-pass such areas; to the fact that no case disputing that roads are a contributory factor to road accidents "would be accepted by the people as a whole"; to the known existence of "thousands of black spots" where accidents take place, and to the estimates that though it costs about £3000 "to eliminate one accident a year in any one black spot," every accident is costing £500; and to the strong economic case, which he supported by figures in pounds, shillings and pence, for a road programme to improve and cheapen indus-

trial production. From the other side of the House Mr. Callaghan instanced the remarkable fact that if the average speed of London's omnibuses could be raised by one mile per hour there would be a saving to the London Transport Executive of £2,000,000 a year. Yet the only reference to increased expenditure upon road improvement was to "plans" for improvements costing a mere £22,000,000 to be "begun" next year!

As was to be expected of a debate upon such a subject, it ranged over a very wide field, far too wide to be fully surveyed here. Naturally enough that much-criticised recent statement of the Select Committee that it had received no convincing evidence of deterioration of the roads came up for discussion. It emerged that Mr. Nicholson, who was chairman of the sub-committee concerned, felt that "engineers do not produce factual evidence. It can be produced when roads are seen to deteriorate and when they collapse . . . A mere expression of opinion that a state of affairs underneath the ground on large stretches of road is dangerous . . . is quite valueless." That surely comes perilously close to rejecting the opinion of a responsible engineer that a bridge is too weak to carry the traffic until the bridge actually falls down! Bouquets, very justifiably, were showered, amongst others by Mr. Nicholson himself, upon the work of the Road Research Laboratory; and the "niggardly" way in which it was treated financially was, again justifiably in our view, criticised. Viscount Hinchingbrooke summed up vigorously all the very strong arguments that exist for the spending of really substantial sums upon road improvement. But, in the main, those who took part in the debate discussed the safety aspect. Repeatedly speakers asked for more control of road users, more restriction, more training and especially for more propaganda. The figures of deaths and injuries on the road are, indeed, shocking. Many speakers wanted them to be so presented as to "shock" the public into their true meaning, in the hope that thereby road behaviour would be improved and accidents thus reduced. But ingenious methods of presenting statistics intended to shock the public can, in our opinion, have no more than a transient effect. For repeated "shock" doses have less and less effect. Again, we remain profoundly doubtful about the true effect of propaganda. Undoubtedly it does serve some useful purpose. But, after all, it is not the habitually reckless and careless who cause accidents, it is those who, momentarily, have been less careful than usual, and there is a limit to what propaganda can do to cure that form of human frailty. By contrast there is scarcely any limit to what can be done by road improvement to reduce the number of opportunities (at present very large indeed) for road users to make those occasional faulty and hasty judgments, that, tragically, lead sometimes to deaths and injuries. Nor is that all. Almost without exception improvements undertaken to make roads safer contribute also to a freer flow of traffic and are thus additionally justified on economic grounds. In the view of engineers road accidents will only substantially be reduced in numbers when more is spent upon the roads.

At about the time when the debate was taking place the Engineer's Guild made public a proposal that it has placed before the Minister for a more systematic investigation of accidents than has hitherto been made. Such an investigation, within its field, might do something to meet Mr. Nicholson's plea in the debate "for more information about the roads and less vague talk." Yet we confess that we doubt whether the investigation proposed, some particulars of which are given elsewhere in this issue, would really reveal much more than is known already. For local authorities are already aware of the "black spots" for accidents in their areas and the highway engineers are equally aware what are the road defects in such places that need rectification. The true value of a systematic investigation of accidents by competent highway engineers along the lines proposed would be that publication of the results might well remove some of the misconceptions bred by the statistics of accidents compiled by the police. For the latter, the police not being road engineers, very naturally play up human failure as the cause of accidents and play down the important influence of road defects as a contributory factor. As the debate proved, there are still very many who think that accidents could be substantially reduced in number if only people could be made to behave better. But in our view they behave, as a rule, very well already. Statistics that revealed clearly how very often it is a road defect, not ingrained recklessness, that leads road users to take those apparently rash and foolish actions which those who favour propaganda criticise, might serve a useful purpose. They might, indeed, bring about a change of heart and greater unanimity in pressing the Government to take the appropriate action.

Obituary

MAJOR SIR HEW ROSS KILNER

We have learned with regret of the death of Major Sir Hew Ross Kilner, M.C., which occurred at Weybridge on Sunday, August 2nd.

Sir Hew, who was sixty years of age, had only recently retired, through continued ill health, from the board of Vickers-Armstrongs, Ltd., where he had been deputy chairman and managing director (aviation) since 1945.

Hew Kilner was educated at Cheltenham College and proceeded to the Royal Military Academy, Woolwich. After service in the 1914–18 war as a Regular Officer in the Royal Artillery, he held the appointment of Staff Captain in the War Office for four years and had five years' experience as an Instructor in Gunnery. In 1930 he joined Vickers-Armstrongs, Ltd., becoming a special director and general manager of its Southern Engineering Works in 1931, and a director in 1936. In 1940, in view of the increasing importance of aircraft production he was appointed general manager of the aircraft section, since when his main interests have been concerned with aircraft. To Sir Hew must be given much of the credit for the organisation behind the production of the famous aircraft which this company contributed, particularly during the early critical phase of the last war. He was appointed managing director (aviation) in 1944 and in 1946 assumed also the position of deputy chairman of Vickers-Armstrongs, Ltd. He was knighted the following year. Sir Hew was also a director of the parent company, Vickers, Ltd., and a director and chairman of Cooke, Troughton and Simms, Ltd.

Literature

Oxidation of Metals and Alloys. By O. Kubaschewski and B. E. Hopkins. London: Butterworth's Scientific Publications, Bell Yard, Temple Bar, W.C.2. Price 35s.

Whereas corrosion due to the exposure of metals to polluted atmospheres and to the corrosive attack of liquids at atmospheric or slightly raised temperatures is an old problem, the oxidation of metals at high temperatures has only of recent years come to be recognised as a practical issue of the highest importance. The development of the gas turbine and the jet engine has focused attention on many metallurgical problems, among them being the properties and behaviour of the products of metal-gas reactions at high temperatures. The surface oxidation of metals and alloys has, however, been studied in other connections for many years, and a vast amount of information has accumulated on the constitution of scale found on iron and steel and of the oxidised layers on other metals and alloys, on the mechanism of oxidation, the kinetics of diffusion and reaction rate, and on preventive measures and protective coatings.

There must be general agreement with the authors of this book on the "Oxidation of Metals and Alloys" that the time is opportune to consider the problem of oxidation as a whole and to undertake a critical review of the present state of knowledge of the subject. The book is written for the benefit of those who wish to understand and interpret the theoretical work that has been done, to appreciate the evidence on which it is based, and so apply the results to experimental work on which they may be engaged, whether this may be directed towards the elucidation of some aspect of the theory or to the development of some alloy to meet a given combination of oxidising conditions. This has involved some division in the theoretical and experimental treatment of the subject, but it has been done without disadvantage to the reader with more limited interests, as the authors have not hesitated to repeat in another connection evidence which may have already been used in one part of the book.

As the authors point out, this is a period of new ideas and theories on the subject of the oxidation of metals, and no completely satisfactory explanation of the mechanism of all the diverse phenomena encountered has yet been evolved. A metal may have three temperature ranges in each of which a different time-relationship governs oxidation. In one temperature range the parabolic relationship is approximately obeyed, at higher temperatures the tendency may be towards a linear relationship, whereas at lower temperatures oxidation may follow a logarithmic law. No one theory covers all the matters which need explanation, but a clear account is given of the parabolic, logarithmic and cubic time-oxidation relationship and of the underlying theory of the production of thin films, the formation of successive layers of several oxides and of the oxidation of alloys. On the experimental

side a large amount of information has been collected together on the rates of oxidation of the metals and the effect of alloy additions. These effects may be very pronounced; for example, 0·01 to 0·02 per cent of aluminium almost completely suppresses the oxidation of liquid zinc and cadmium at the melting point, and greatly reduces that of the solid at slightly lower temperatures. The beneficial effect of aluminium on the resistance to oxidation of many metals and alloys is, of course, due to the highly protective oxide layers formed. Metallic electrodeposited coatings find some applications but have distinct limitations at high temperatures, at which oxides, silicides or (if adequate adhesion is obtained) ceramic coatings are more effective.

The term "oxidation" is used to cover surface reactions involving gases other than oxygen, and practical aspects of the effect of gases containing sulphur are described. The book is confined to oxidation of metals and alloys at temperatures of 100 deg. Cent. and above. Thermodynamic and thermal data are tabulated for all possible constituents of oxidised surface layers.

The book should prove to be an indispensable source of information to all interested in the practical or theoretical aspects of the subject, and Dr. Vernon's commendation in the foreword may be wholeheartedly endorsed.

Investment Castings for Engineers. By R. L. Wood and D. von Ludwig. London: Chapman and Hall, 37, Essex Street, W.C.2. Price £4.

The technology of foundry practice is something of a mystery to the average engineer. Too little is known by him of the difficulties of the foundrymen and of the fundamental physical laws governing the casting and solidification of molten metals. Thus, when in 1942 the investment casting process (or, to give it its more widely known name, "the lost wax process") was introduced into this country from America, he was ready to hear and believe that components, whatever their shape and size, could be cast to within 0·001in of their requirements. This overselling of the process in its early stages of development has wrought irreparable harm, especially when the engineer saw its shortcomings and consequently lost considerable faith in its value to him as a means of fabrication. The past ten years has seen a more sober attitude adopted as the process develops along its own specialised lines of production, and this book by Wood and Ludwig does much to put things in their true light.

The first half of the book, consisting of some ten chapters, is mainly of interest to foundrymen, since it details the various stages of the process, but even so the engineer will find much to interest him; e.g. in discussing the frozen mercury pattern process it is stated (page 109), "... the commercial limits of precision which are now accepted as normal for the Mercast process are identical with those quoted for wax or plastic," &c. The second part of the book is of more particular interest to engineers. There is an excellent chapter which discusses the machining of investment castings and one sentence with which the reviewer finds himself in agreement is "where surfaces are to be faced, milled, turned or otherwise machined, the fixture must index the casting from the same surface used by the foundry to inspect the final casting." Too often this point is overlooked when the engineer is designing machining jigs and fixtures. Another chapter outlines some machinability tests on stainless steel. There are three chapters of interest to designers, namely, "Product Design Development by Means of Investment Castings," "Castings to Replace Fabricated Parts," and "Design Suggestions for Investment Castings." These chapters contain many excellent illustrations and examples of investment castings and the problem is best summed up by the authors: "Like any other new process, it will find its proper place in the metal forming field when design engineers are familiar with both its possibilities and its limitations." Two chapters are included which are of interest to metallurgical engineers, "Investment Castings for Chemical and High-Temperature Resistant Applications," and "Some Metallurgical Observations of Investment Cast Alloys." While one is bound to question the statement, "... the vibration and fatigue resistance of the cast structure are usually superior to that of the forged and machined metal," the series of conclusions detailed on pages 445–447 confirm many of the opinions held in this country.

This book sets out to put the investment casting process in its true perspective, and in this it succeeds admirably. The engineer will find its common sense and logic very refreshing after some of the previous literature he may have read on this particular subject. The book can be recommended to all engineers, whatever their calling, and foundrymen, purchasers and users of castings will find much to interest them.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

SOME NOTES ON PLANE FRAMES NOT OBEYING HOOKE'S LAW

Sir,—If Mr. Charlton will re-read my article with more care, and note what I did say, and do, rather than what he imagines I said and did, he will find:—

(1) That nowhere do I make use of Castigliano's theorems. In fact, I go to some trouble to indicate their inadmissibility as a reason for the whole article, and the suggested methods of approach.

(2) That two out of the three examples I gave show that the method applies to redundant structures. It can equally well be applied to internal redundancies of any type. It is true that during the solution I temporarily removed the redundancies, thus rendering the structures determinate for the time being; but surely Mr. Charlton has not been misled by that? To be told that the apparent success of my method depends on the fact that I applied it to statically determinate frames only, can only mean that his imagination has run away with him.

(3) That I made no attempt to use P/W as constant save in structures where the redundancies were non-existent or were temporarily removed.

(4) That simple statics will show that for such structures $P/W=\Delta/\delta$ without any necessity to resort to his clumsy approach via complementary energy. My concluding remarks on Problem 2 dispose of any idea that I attempted to use such a relation at other times.

In fact, I can find no point where Mr. Charlton's criticisms are valid, as they are based on misreading or misunderstanding my article in every case. At the present time, I fear Mr. Charlton is spending much time and energy rediscovering old, well-established principles through a cloud of awkward mathematical notation. As his one-time teacher (though not of advanced theory of structures) I find this disappointing. May I urge him to put his mathematics on one side for a time and really get hold of basic structures. If he will, one of his undoubted talents should go far along the right road, instead of being unable to see the fundamental wood for mathematical trees, and might then offer the sound criticism which I for one would welcome.

J. W. H. King

Queen Mary College, London, E.1,
July 30th.

THE "INTRINSIC EFFICIENCY" OF A FLOW TYPE AIR COMPRESSOR

Sir,—The very interesting article by Mr. B. Downs raises once more the question of the definition of compressor (or turbine) efficiency.

As the author of the article points out, when a compressor delivers air directly into a turbine inlet, the efficiency of the whole set is not equal to the product of the isentropic efficiencies of compressor and turbine. But this difficulty is not new; the case considered by Mr. Downs is quite similar to the case of a multi-stage compressor or turbine, where, assuming a constant-stage efficiency, the latter does not equal the isentropic efficiency of the machine. It is well known that it is possible to make allowance for this difference by introducing the so-called "reheat factor." The same concept could also be used in the case of a compressor followed by an air turbine; the value of the reheat factor would then be (using Mr. Downs' notation):

$$\mu=\frac{\eta_{oi}}{\eta_{os}}=\frac{T_2-T_3'}{T_2'-T_1}.$$

But as a matter of fact an actual air compressor never delivers directly into the turbine inlet; there is always between compressor and turbine a combustion chamber, an air heater or, at least, a storage and transmission system. Therefore the temperature at the turbine inlet is always different from the temperature at the compressor outlet; but the reheat factor, as well as the "intrinsic" efficiency, does not take this variation of temperature into consideration.

I would like to add that I tried to establish, for different arrangements, a more satisfactory definition of compressor efficiency (which I called the "total" efficiency) in my *Thermodynamics of Gas Turbine*, published (in French) in 1949.* In case of a compressor delivering directly into the turbine inlet, assuming that η_{T_0} is independent of η_{os}, the compressor "total" efficiency is identical with the "intrinsic" one. But this concept of compressor efficiency applies only to this very particular case and has not to be generalised.

Dr. P. Chambadal

Paris, July 29th.

Sir,—Mr. Downs is to be complimented on recommending to engineers the use of the "intrinsic efficiency" on thermodynamic grounds and he goes to some length to justify his case. The writer wishes to observe that the "intrinsic efficiency" is not a new ratio and that Mr. Downs has no reason for introducing another phrase into our terminology which is already overloaded. Keenan[1] defines the "effectiveness" of a turbine stage as $W/\Delta b$, where W is the external work performed and Δb is the decrease in available energy. It would be reasonable to define the "effectiveness" of a compression stage as $\Delta b/W$, where W is the external work given to the fluid and Δb is the increase in available energy. If Mr. Downs examines the references given here he will find that Keenan demonstrates the value of the ratio, "effectiveness," by means of the availability function (b)—this is just the available energy with reference to the surroundings. The writer suggests that credit be given to Keenan, who introduced the term "effectiveness" in 1932[2] and that this word be preferred to "intrinsic

* Commented on in The Engineer of January 27, 1950.
[1] Keenan, *Thermodynamics*, John Wiley and Sons.
[2] Keenan, *Mechanical Engineering*, Vol. 54 (1932), pages 195–204.

efficiency," which Mr. Downs proposes. It is further suggested that thermodynamic irreversibilities would be much more clearly understood were such ratios as "effectiveness" or "intrinsic efficiency" adopted.

In a footnote Mr. Downs writes: "Isentropic processes are considered as adiabatic and isentropic processes throughout." To say the least, this is incomprehensible. A reversible adiabatic process is an isentropic process. The writer trusts the footnote is a typographical or printer's error.

EDWARD A. BRUGES, B.Sc.
Lecturer in Mechanical Engineering,
The University, Glasgow.
July 28th.

"BRITANNIA" LOCOMOTIVE

SIR,—I have read with great interest Mr. O. S. Nock's review of the Railway Executive's recent report on the performance and efficiency tests on its "Britannia" locomotives. It is, of course, quite proper to omit, from a report concerned primarily with performance, an explanation as to how details, such as driving wheels which slipped on their axles and reversing gears reputed to need attention from the coal hammer when they stick in full gear, &c., come to be incorporated amongst "the best features of all previous practice." It cannot be disputed, moreover, that on the basis of the figures published, a case can be made out in favour of the new engines.

But we must remember that, being on the point of abolition under the Transport Act, 1953, the Railway Executive has to try and justify itself in the face of an alarming level of criticism from the users, who judge merely from the service it provides, and with far from unanimous backing on the part of its own supporters. In publishing at the present time so favourable a report on one of its products, the success of which is by no means generally accepted, the Executive would find it hard to prove that no such ulterior motive does in fact exist. Engineers do not attach the same significance to figures, however convincing, if they are open to suspicion of being produced, even partly, to suit political ends.

Mr. Nock hails the advent of a large boiler as if it was a remarkable new invention. If sheer boiler size is such an important criterion of successful design we must remember that the late Sir Nigel Gresley's A.1 "Pacifics" of 1922, weighing nearly 2 tons less than the "Britannias," had boilers with over 250 square feet more heating surface. Moreover, nearly thirty years' subsequent development in alloy steels was available to assist British Railways in making the most effective use of the overall weight which it had chosen. These are physical facts, quite apart from the theories which any particular individual may hold upon performance.

Despite the remarkable nature of the test figures, both at Rugby and on the road, it is curious that when a demonstration is required of the superiority of the 94-ton "Britannias," which the public can judge for themselves in regular service without the "assistance" of reports and "interpreters" of reports, this can only be given by relaxing weight restrictions in East Anglia to enable these engines to take over the duties of mere 69½-ton B.12s.

R. G. B. GWYER,
M.A., A.M.I.Mech.E., A.M.I.E.E.
Manchester, August 1st.

A FOUNDRY PLANT FILM.—A comprehensive pictorial record of all stages in the production of Blackheart malleable iron castings is given in a film entitled "Modern Malleable" made at the Tipton foundries of Hale and Hale, Ltd. This 16mm sound film in black and white, with a running time of thirty-two minutes, will be loaned free to technical bodies, recognised institutes and associations, schools and universities, apprentice associations and industrial concerns interested in the use of ferrous metals. Bodies interested in borrowing the film should apply to Hale and Hale (Tipton), Ltd., Dudley Port, Tipton, Staffordshire.

International Electrotechnical Commission, 1953

WE learn from the British Standards Institution that the 1953 series of meetings of the International Electrotechnical Commission was held in Opatija, Yugoslavia, from June 22nd to July 1st. Seventeen countries were represented and about 300 delegates attended the meetings of the various committees. The largest delegation was that from the United Kingdom, comprising forty-three members appointed by the British National Committee (under the ægis of the British Standards Institution). The opening session was on June 22nd. The following is a brief summary of the results achieved at the meetings of the technical committees:—

Graphical Symbols.—A list of symbols of general application (e.g. variability) and symbols relating specifically to terminals and brushes of rotating machines and to transformers was discussed and revised lists are to be prepared for consideration at the next meeting. A sub-committee was also set up to prepare a scheme of classification for diagrams of connections. This is part of the work relating to the revision of the I.E.C. publications on graphical symbols.

Radio Communication.—Methods of measurement of the characteristics of broadcast television receivers were discussed, and agreement was reached on many of the proposals put forward by the Secretariat (Netherlands). A document on the procedure for applying basic climatic and mechanical robustness tests to radio components was approved for publication. A colour code for ceramic capacitors and a specification for fixed paper capacitors were passed for circulation to the National Committees for approval. Agreement was also reached regarding a group specification for ceramic capacitors and for carbon resistors; but these documents are only for internal use by the I.E.C. Committee in the drafting of detailed specifications and will not be printed in their present form as I.E.C. recommendations. A sub-committee on high-frequency cables and connectors was set up, and it was decided to undertake the study of piezo-electro crystals, with a view to the preparation of a specification.

The question of the standardisation of radio transmitters was briefly discussed, and it was decided to ask the Secretariat (Netherlands) to formulate some proposals in order that the National Committees can consider whether the time is ripe for such standardisation to proceed.

Insulating Materials.—The committee on insulating materials is considering the standardisation of methods of test for specific properties, and at the Opatija meeting reviewed in detail the tests for tracking, volume and surface resistivity, and heat resistance.

Switchgear and Control Gear.—Chapter 1 (rules for short-circuit conditions) of the I.E.C. specification for circuit breakers has been under revision for some years, and the final text was approved for publication by the appropriate committee. Chapter 2 (rules for normal load conditions) was reviewed and a new draft will now be prepared and circulated to the national committees for their approval. A document dealing with unit testing of circuit breakers for making capacity and breaking capacity has also been completed for circulation to the national committees for approval.

Electric Cables.—A revision of the I.E.C. specification for tests on impregnated paper-insulated lead covering cables for voltages of 10kV up to 66kV was completed for circulation, and preliminary attention was given to a specification for low-pressure oil-filled cables.

Power Converting Equipment.—A draft specification for mercury arc rectifiers has been under discussion for some years, and although still incomplete in certain respects, it has now reached a stage when it can be circulated to the national committees for approval. In view of this it was decided at the Opatija meetings that work should be started on a specification for dry type rectifier equipment.

Lamps and Related Equipment.—Draft specifications for tubular fluorescent lamps and for ballasts for fluorescent lamps were completed for circulation to the national committees for approval.

A sub-committee was set up to deal with lighting fittings. This committee will work in close collaboration with the International Commission on Rules for the Approval of Electrical Equipment (C.E.E.) in the preparation of a specification for fittings for tungsten filament lamps. Work is still proceeding on the subject of colours of fluorescent lamps.

Lightning Arrestors.—A draft specification for lightning arrestors of the type incorporating non-linear resistors was under consideration. Further discussion will, however, be necessary before a draft can be prepared for approval by the national committees.

Electronic Valves.—A specification for electronic valve bases had already been circulated to the national committees for approval. As the result of comments received, however, a number of additions and modifications to the text were made at the meetings in Opatija, and a revised draft will now be circulated. The dimensions of sub-miniature valves were also discussed and a draft specification will be prepared by the Secretariat (Netherlands) for circulation to the national committees for comment.

Electric and Magnetic Magnitudes and Units.—A draft resolution on the rationalisation of the M.K.S. system of units was discussed and adopted for circulation. It was also agreed to invite the International Union of Pure and Applied Physics to hold a joint meeting with the I.E.C. Committee on Magnitudes and Units to discuss how the decision regarding rationalisation can best be implemented.

COMMITTEE OF ACTION

Several matters of policy and procedure were dealt with by the Committee of Action at their meeting on July 1st. It was decided to institute an annual lecture, to be known as "The Charles le Maistre Lecture" in commemoration of the invaluable work done by the late Mr. C. le Maistre as General Secretary from the formation of the I.E.C. in 1904 until his death on July 5, 1953.

A revised scale of financial contributions from the national committees was adopted. Effectively this will mean that the more highly industrialised countries will be asked to increase their subscriptions by about 20 per cent, while the smaller countries—many of which had not adopted the scale of contributions drawn up two years ago—were asked to do so as soon as possible.

Arrangements for the jubilee meeting to be held in Philadelphia in September, 1954, were discussed. Amongst other features, it is hoped that a few papers by prominent personalities from different countries will be presented. Meetings of several technical committees will also be held, as well as meetings of the Committee of Action and of the Council.

Books Received

Electro-Magnetic Machines. By R. Langlois-Berthelot. London: MacDonald and Co., (Publishers), Ltd., 16, Maddox Street, London, W.1. Price 65s.

The Principles and Practice of Management. Edited by E. F. L. Brech. London: Longmans, Green and Co., Ltd., 6 and 7, Clifford Street, W.1. Price 50s.

Wells and Boreholes for Water Supply. Second edition. By J. E. Dumbleton. Surrey: The Technical Press, Ltd., Gloucester Road, Kingston Hill. Price 17s. 6d.

Flames, Their Structure, Radiation and Temperature. By A. G. Gaydon and H. G. Wolfhard. London: Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 55s.

Information Theory and its Engineering Applications. By D. A. Bell. London: Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, W.C.2. Price 20s.

London's Water Supply, 1903–1953. *Review of the Work of the Metropolitan Water Board.* London: Staples Press, Ltd., 14, Great Smith Street, Westminster, S.W.1. Price 15s.

Design of Structural Welded Details. By F. H. Abrahams. Surrey: The Association of Engineering and Shipbuilding Draughtsmen, Onslow Hall, Little Green, Richmond. Price 3s.

Strength of Materials. Second edition. By John W. Breneman. London: McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, London, E.C.4. Price 25s. 6d.

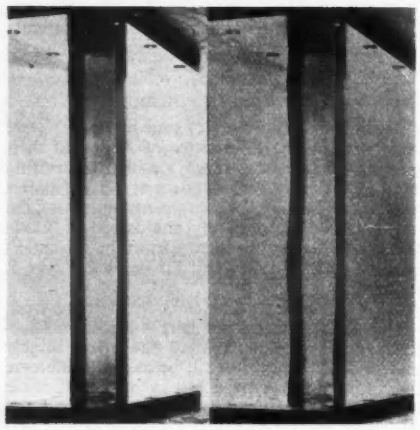
The Stability and Strength of Thin-Walled Steel Struts

By A. H. CHILVER, B.Sc., Ph.D.

This article is concerned mainly with the compression strength of steel channel sections. The struts studied are those known as "cold-formed" steel sections; they are generally manufactured from thin flat steel strip by a continuous cold rolling process; they may be formed also by cold pressing short lengths of steel strip into the required shape. It is found that the strengths of sections manufactured in this way may be predicted with reasonable accuracy.

THE wider use in recent years of thin-walled structural components has promoted considerable interest in the local instability of these members. In fact, problems associated with local buckling may arise in any structural members in which there are thin component flat plates under compression or shearing stresses.

An important advantage of thin-walled steel construction lies in the considerable savings of weight which can be effected when the light-gauge structure is compared with the more conventional hot-rolled types. In addition, the cold-formed process makes available an almost unlimited range of structural shapes. Cold-formed steel sections have been widely used both in this country and in the United States; experience up to the present time suggests that this new form of construction is most suited to lightly-loaded buildings and the secondary members of large frames. The sections are used as beams, struts and ties; they are frequently employed as the main members of light prefabricated girders for use as roof trusses and floor beams. In these applications channel sections are the most commonly used components; they may be welded to form both box and I sections. The webs and flanges of these channel sections are essentially flat component plates.



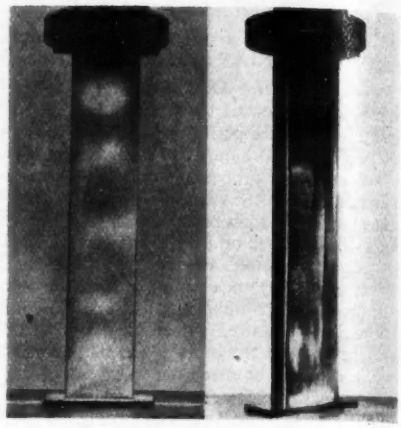
(*a*) (*b*)
(a) In the Early Stages of Loading
(b) At the Elastic Instability Stress

Fig. 1—Condition of a Compressed Plain Channel

The tests described in this paper were carried out at the engineering laboratories of the University of Bristol on steel sections supplied by member firms of the Cold-Rolled Sections Association of Birmingham.

A problem of particular interest at the present time is that of the compression strength of thin-walled steel channels. Both plain and reinforced channel sections are widely used as struts. This article is concerned with the shorter struts which are prone only to local instability failure. In the early stages of the compression of a short thin-walled strut the walls of the strut are uniformly stressed. A plain channel section is shown in Fig. 1*a*. At some critical value of the compression stress the walls of the section buckle outwards (Fig. 1*b*). This outward buckling is not restricted to any one component plate of the section, but occurs in all the component plates. In this buckled form there are usually a number of longitudinal waves. Buckling of the strut is not necessarily accompanied by complete collapse, and it is important to distinguish between initial buckling and ultimate failure of the section. Beyond the buckling stage further compression of the strut is possible, since the corners of the channel are relatively undistorted and can withstand additional loading. The ultimate strength of the strut is reached when the compression yield stress is developed at the corners of the channel. The final collapse takes place with a crippling of the strut at the most heavily distorted longitudinal wave. A number of collapsed sections of varying lengths are shown in Fig. 2.

To increase the local instability strength of a plain channel, a reinforcing longitudinal flange is sometimes formed at the extreme edges of the channel. These reinforced sections, which are usually referred to as "lipped" channels, behave in much the same way from the local instability point of view. If the reinforcing "lip" is sufficiently stiff, buckling at the extreme edges of the channel is suppressed in the early stages of loading and the overall local instability strength is increased. The longitudinal buckling waves in the web and flanges of a compressed "lipped" channel are shown in Figs. 4*a* and 4*b*. A set of collapsed sections is shown in Fig. 3.



(*a*) (*b*)

Fig. 4—Buckling Waves in Web and Flanges of a "Lipped" Channel

The elastic instability of a thin-walled channel strut was first discussed theoretically by Stowell and Lundquist,[1] who treated the channel as an assembly of flat plates. Subsequent investigations have discussed the problem in much the same way. A treatment of the problem in this form depends upon the accurate assessment of the boundary conditions along the edges of each component plate. The dimensions of a simple channel section are shown in Fig. 5; the length of the channel between the compressed ends is *L*. The locally unstable form of the cross section is indicated in Fig. 5*c*. A theoretical treatment of this problem is possible if it is assumed that the buckled mode is one involving only small outward deflections of the component flat plates. Due consideration must also be given to the conditions of

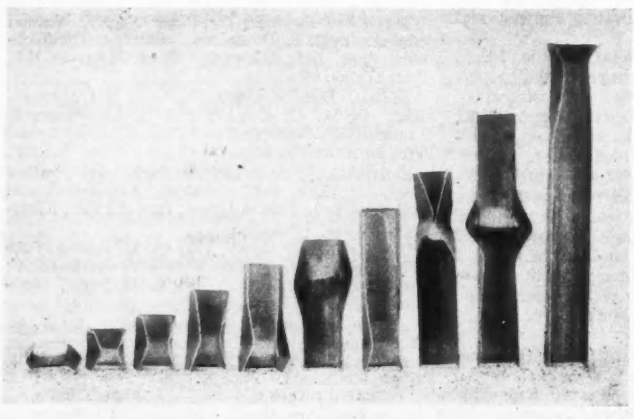


Fig. 2—Collapsed Plain Channels of Varying Length

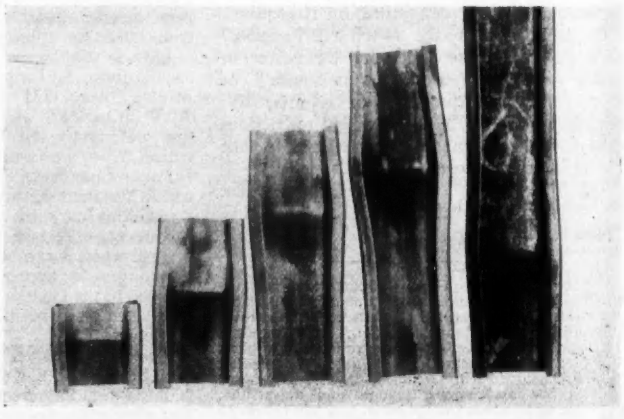


Fig. 3—Collapsed "Lipped" Channels of Varying Length

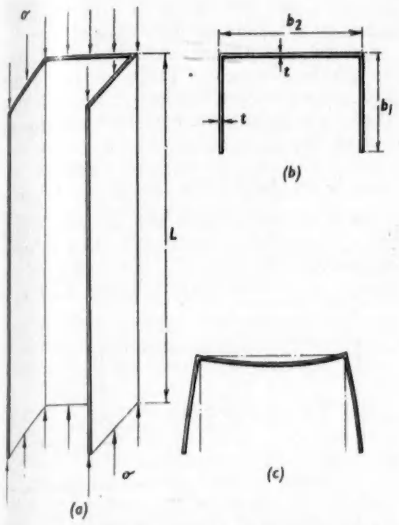


Fig. 5—(a) Compression of a Plain Channel, (b) Dimensions of a Plain Channel, (c) Buckled Mode of a Plain Channel

support at the corners of the channel. Suppose σ_{cr} is the critical stress for the buckled mode ; parameters p and q are then defined as

$$\left[p^2=\frac{m^2\pi^2b^2}{L^2}+\sqrt{\frac{\sigma_{cr}b^2t}{D}\cdot\frac{m^2\pi^2b^2}{L^2}}\right]_{1,2},$$

$$\left[q^2=\frac{m^2\pi^2b^2}{L^2}+\sqrt{\frac{\sigma_{cr}b^2t}{D}\cdot\frac{m^2\pi^2b^2}{L^2}}\right]_{1,2},$$

where m is the number of longitudinal half-waves in the buckled form, and D is the "flexural stiffness" of each component plate, given by

$$D=\frac{Et^3}{12(1-\nu^2)},$$

where E is the modulus of elasticity and ν is Poisson's ratio. Other parameters, r and s, are defined as

$$\left[r^2=p^2-\nu\frac{m^2\pi^2b^2}{L^2}\right]_{1,2},\quad\left[s^2=q^2+\nu\frac{m^2\pi^2b^2}{L^2}\right]_{1,2}.$$

In all these relations the subscripts 1, 2 refer to the flange and web of the channel respectively. For a plain channel of the type shown in Fig. 5 the critical stress σ_{cr} is then the root of the equation

$$\left[\frac{fb}{fs}\right]_1=\frac{b_1}{b_2}\left[\frac{sb}{ss}\left(-1\pm\sqrt{1+\frac{bb\,.\,ss}{sb^2}}\right)\right]_2, \quad (1)$$

in which the "stability functions" are defined as

$$fb=-pq[(r^4+s^4)\cosh p\cos q+2r^2s^2]+(p^2s^4-q^2r^4)\sinh p\sin q,$$
$$fs=(r^2+s^2)(ps^4\cosh p\sin q-qr^4\sinh p\cos q),$$
$$sb=(r^2+s^2)(q\sinh p\cos q-p\cosh p\sin q),$$
$$ss=-(r^2+s^2)^2\sinh p\sin q,$$
$$bb=2pq(1-\cosh p\cos q)+(p^2-q^2)\sinh p\sin q.$$

The significance of the "stability functions" lies in the fact that $fb=0$, for example, defines

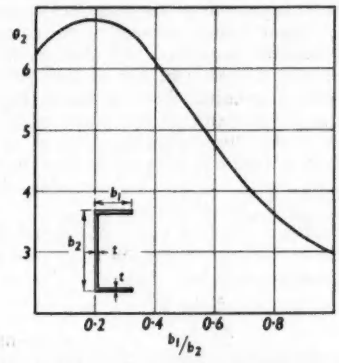


Fig. 7—Minimum Values of θ_2 for Plain Channels

the stability of a single plate with one longitudinal edge free and the other built in, while $sb=0$ corresponds to one edge simply supported and the other built in. The other stability functions have a similar significance, the letter f denoting a free edge, b a built-in edge, and s a simply-supported edge. Equation (1) is general to the extent that all modes of instability are included in the solution. (A solution of the problem for symmetrical modes of buckling is given in Ref. 2.[2]) The solution of equation (1) for the particular case in which $b_1=b_2$ is given in Fig. 6, in which critical values of $\sqrt{\sigma_{cr}b^2_2t/D_2}$, (θ_2) are plotted against L/b_2. For the short struts there is only one half-wave of buckling, given by $m=1$. After a certain L/b_2 ratio is exceeded the relevant mode of instability involves two longitudinal half-waves, given by $m=2$. Further increases in L/b_2 are accompanied by only small changes in the critical stress, the parameter $\sqrt{\sigma_{cr}b^2_2t/D_2}$ remaining almost constant at about 2·92. This value of the stress parameter gives the minimum local instability stress of the section. For any other value of b_1/b_2 there is a corresponding minimum value of $\sqrt{\sigma_{cr}b^2_2t/D_2}$. These minimum values are given in Fig. 7 for values of b_1/b_2 from 0 to 1.

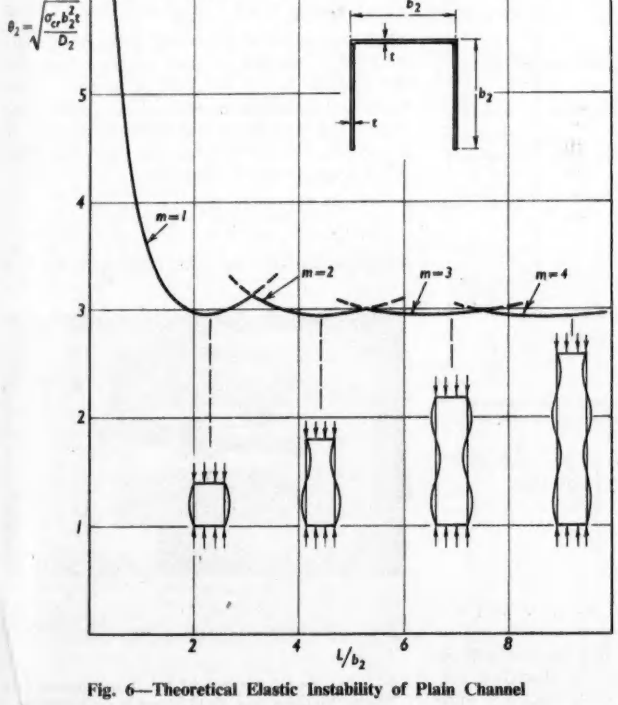


Fig. 6—Theoretical Elastic Instability of Plain Channel

For a reinforced channel section, Fig. 8, the reinforcing lips or flanges have high flexural stiffnesses but negligible torsional stiffnesses. In all the sections tested the lips were sufficiently stiff to prevent premature buckling of the flanges at the extreme edges. Under these conditions the extreme edges of the channels are effectively simply supported. In this case the elastic buckling stress σ_{cr} is given by the solution of the equation

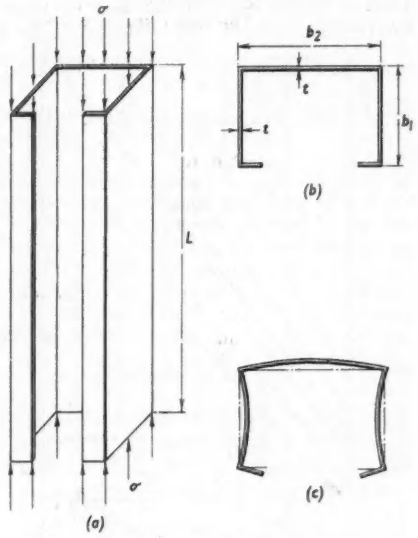


Fig. 8—(a) Compression of a "Lipped" Channel (b) Dimensions of a "Lipped" Channel (c) Buckled Mode of a "Lipped" Channel

$$\left[\frac{sb}{ss}\right]_1=\frac{b_1}{b_2}\left[\frac{sb}{ss}\left(-1\pm\sqrt{1+\frac{bb\,.\,ss}{sb^2}}\right)\right]_2, \quad (2)$$

in which the stability functions are defined as before, and the subscripts 1, 2, refer to the flange and web of the channel respectively. The solution of equation (2) gives buckling stresses which vary in much the same way as those for a plain channel. The important variation of the minimum values of $\sqrt{\sigma_{cr}b^2_2t/D_2}$ for values of b_1/b_2 from 0 to 1 is given in Fig. 9.

The elastic buckling stresses were studied experimentally by compressing short lengths of channel sections between the flat parallel platens of a testing machine. The use of rigid flat ends reduces column instability

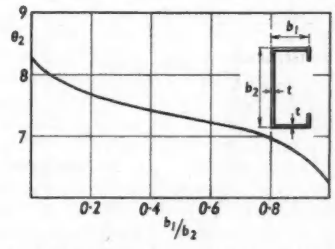


Fig. 9—Minimum Values of θ_2 for "Lipped" Channels

effects to a minimum. The critical stresses of the compressed channels were found from measurements of the small outward bending deflections of the component plates at loads less than the buckling load. If δ is the outward bending deflection of a component plate and P is the corresponding applied load, then δ varies almost linearly with δ/P in the early stages of loading. Typical curves of this type are shown in Fig. 10. According to Southwell's principle, the slope of the

δ—δ/P line corresponds to the critical load P_{cr}. Suppose

$$\theta_2=\sqrt{\frac{\sigma_{cr}b^2_2t}{D_2}} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

then

$$\sigma_{cr}=\frac{E}{12(1-\nu^2)}\left[\frac{\theta t}{b}\right]^2_2. \quad . \quad . \quad . \quad (4)$$

Then it would be expected that σ_{cr} varies inversely as $[b/\theta t]^2_2$, if the values of E and ν

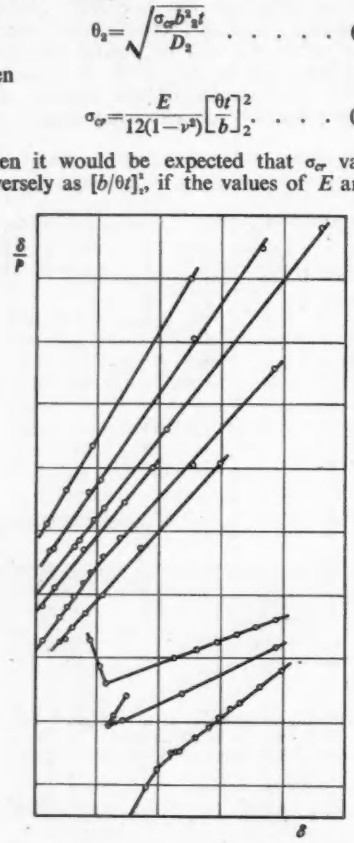


Fig. 10—δ against δ/P Curves for Plain and "Lipped" Channels

are constant. The measured critical stresses for a few lipped and a number of unlipped sections are shown in Fig. 11. The values of θ_2 in equation (3) have been taken from Figs. 7 and 9. Obviously there will be deviations from the elastic instability stress in the regions of high stress, where the yield stress of the material becomes important. There is a gradual transition from the range of elastic buckling into the zone of failure by yielding.

Although there is much information available on the ultimate strength of single flat plates in compression, considerably less is known of the ultimate strength of thin-walled struts, especially steel sections. A simple analysis for a single flat plate supported along both longitudinal edges can be

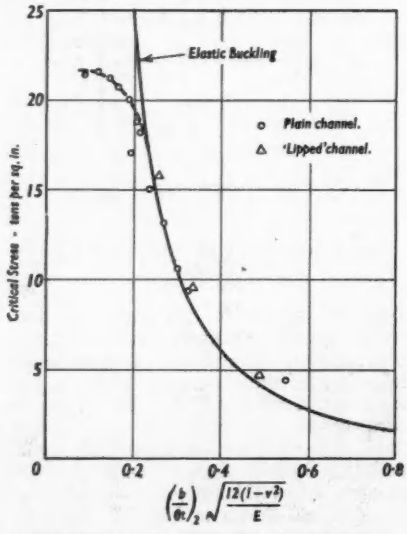


Fig. 11—Critical Stresses for Channel Struts

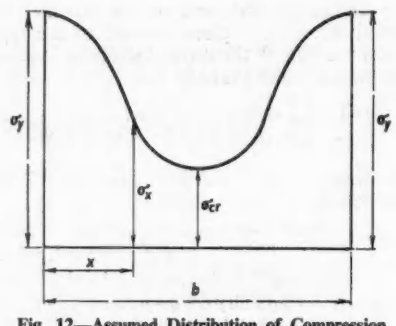


Fig. 12—Assumed Distribution of Compression Stresses at the Ultimate Load of a Single Flat Plate

made by assuming that in the post-buckled condition the ultimate strength is reached when the supported edges begin to yield. The centre sections of the plate, being unable to withstand additional load, remain stressed at the critical stress σ_{cr}. At ultimate failure the stress distribution across the plate is assumed to take the form shown in Fig. 12. If b is the breadth of the plate, then it is assumed that the compression stress at any distance x from one edge of the plate is given by

$$\sigma_x=f(\sigma_{cr}, \sigma_y, x, b),$$

where f is a function characteristic of single flat plates in compression. Then obviously the equation may be recast as

$$\frac{\sigma_x}{\sigma_y}=f'\left(\frac{\sigma_{cr}}{\sigma_y}, \frac{x}{b}\right).$$

Now the ultimate load is given by

$$P_{ult}=\int_0^b \sigma_x t dx=\int_0^1 \sigma_x btd\left(\frac{x}{b}\right).$$

On substituting for σ_x,

$$P_{ult}=\sigma_y bt\int_0^1 f'\left(\frac{\sigma_{cr}}{\sigma_y}, \frac{x}{b}\right)d\left(\frac{x}{b}\right)=\sigma_y btF\left(\frac{\sigma_{cr}}{\sigma_y}\right),$$

in which F is a function of (σ_{cr}/σ_y) only. The

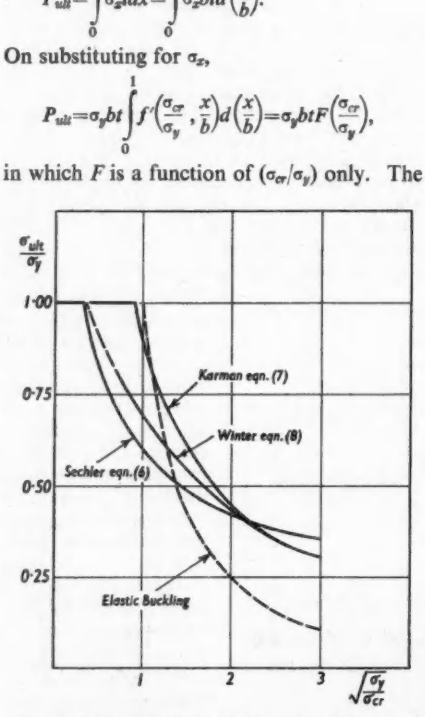


Fig. 13—Comparison of Ultimate Strengths of Structural Sections and Single Plates

ultimate stress, σ_{ult}, for the plate is defined as the average stress at failure. So that

$$\sigma_{ult}=\frac{P_{ult}}{bt}=\sigma_y F\left(\frac{\sigma_{cr}}{\sigma_y}\right).$$

Then

$$\frac{\sigma_{ult}}{\sigma_y}=F\left(\frac{\sigma_{cr}}{\sigma_y}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Most of the investigations into the strength of flat plates have been made by studying the variations of the parameters (σ_{ult}/σ_y) and (σ_{cr}/σ_y); all treatments of the problem reduce to an equation of the type (5).

Sechler and Dunn[3] have suggested that for the post-buckling range of single flat plates, an expression for the stress distribution which is in good agreement with experiment is given by

$$\sigma_x=\tfrac{1}{2}\left[(\sigma_e+\sigma_{cr})-(\sigma_e-\sigma_{cr})\cos\frac{2\pi x}{b}\right],$$

where σ_e is the stress at the extreme edges, and σ_{cr} is the stress; this relation implies that the stress at the centre of the plate is σ_{cr}. This relation agrees well with

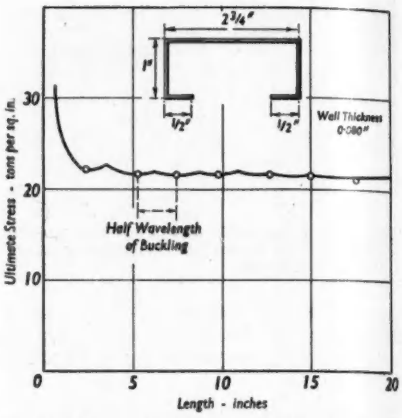


Fig. 14—Compression Tests on a "Lipped" Channel

tests in the elastic range, but for the prediction of ultimate strength Sechler[4] gives the equivalent of the relation

$$\frac{\sigma_{ult}}{\sigma_y}=0\cdot6\left(\frac{\sigma_{cr}}{\sigma_y}\right)^{\frac{1}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

This empirical expression is based on a large number of tests on plates of various metals. Some of the earliest tests on flat plates were carried out by Karman, Sechler and Donnell,[5] who found from tests that

$$\frac{\sigma_{ult}}{\sigma_y}=0\cdot894\sqrt{\frac{\sigma_{cr}}{\sigma_y}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

More recent experimental work by Winter[6] on steel plates led to a relation which can be written in the form

$$\frac{\sigma_{ult}}{\sigma_y}=\sqrt{\frac{\sigma_{cr}}{\sigma_y}}\left(1-0\cdot3\sqrt{\frac{\sigma_{cr}}{\sigma_y}}\right) \quad . \quad . \quad . \quad (8)$$

This expression defines the average strength of a large number of steel plates. Equation (8) applies to plates simply supported on both longitudinal edges. For plates supported on one edge, but completely free on the other, Winter[6] found that the equivalent of an expression of the type

$$\frac{\sigma_{ult}}{\sigma_y}=1\cdot96\sqrt{\frac{\sigma_{cr}}{\sigma_y}}\left(1-0\cdot521\sqrt{\frac{\sigma_{cr}}{\sigma_y}}\right),$$

describes the average test results, and that a

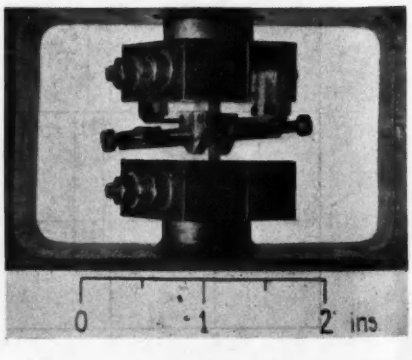


Fig. 15—Test Arrangement for Determination of Elastic Modulus and Yield Stress in Compression

more conservative relation is given by:

$$\frac{\sigma_{ult}}{\sigma_y}=1\cdot252\sqrt{\frac{\sigma_{cr}}{\sigma_y}}\left(1-0\cdot316\sqrt{\frac{\sigma_{cr}}{\sigma_y}}\right).$$

The relevant equations (6), (7) and (8) are compared in Fig. 13. The tests by Winter and Sechler are in good agreement, whereas the Karman relation shows considerable divergence as (σ_{ult}/σ_y) approaches unity. The elastic buckling curve is also shown in Fig. 13.

Tests on thin-walled light alloy sections, as opposed to single flat plates, have been made by Heimerl.[7] For a wide range of tests on light alloy extrusions, Heimerl found that the ultimate strength was accurately given by a relation of the type

$$\frac{\sigma_{ult}}{\sigma_y}=K\left(\frac{\sigma_{cr}}{\sigma_y}\right)^{\frac{1}{2}},$$

in which K is a constant depending upon the type of cross section. In the case of plain channel sections, for example, K is equal to 0·77. The value σ_{cr} in Heimerl's relation is the measured buckling stress, elastic or plastic, depending upon the shape of the compression stress-strain curve.

All these investigations into the ultimate strengths of flat plates, and especially the work of Heimerl, indicate the importance of the parameters (σ_{ult}/σ_y) and (σ_{cr}/σ_y). The tests carried out by the author have been studied in the light of the three important stresses — σ_{ult}, the average compression stress at failure, σ_y, the compression yield stress of the material, and σ_{cr} the elastic buckling stress.

The determination of the ultimate stresses experimentally follows largely the same lines as those adopted for the study of the critical stresses of channel sections; the ultimate stresses for the steel sections of Tables I and II were found from compression tests on varying lengths of each section, in order to find the true minimum collapse strength. The effect of varying the length is shown in Fig. 14. The ultimate stress corresponds to the maximum load divided by the total area of the strut.

The measurement of compression yield stress presents some difficulties owing to the inherent thinness of the steel sections. To overcome these problems a short strip of material was cut from, say, the web of a channel, and machined and filed to a length of 1½in and a breadth of ¼in. The thickness of the strip corresponds to the wall thickness of the strut. For compression testing, the ends of the 1½in strip are held rigidly in blocks which reduce the unsupported length of the specimen to ½in. The specimen is compressed centrally between parallel platens, as shown in Fig. 15. For the measurement of strains a roller extensometer of ½in gauge length, fitted with mirrors, is attached to the specimen. The rigid end blocks prevent rotation of the specimen at the points of application of the compression load. In this way it is possible to record the stress-strain curve of the specimen well into the plastic range. A typical set of compression stress-strain curves is shown in Fig. 16.

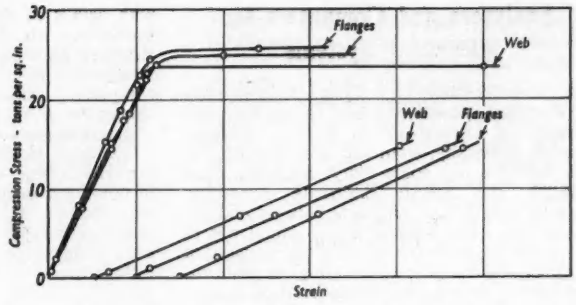


Fig. 16—Compression Tests on Specimens from a 1½in×1in×½in×0·048in Cold-Rolled "Lipped" Channel

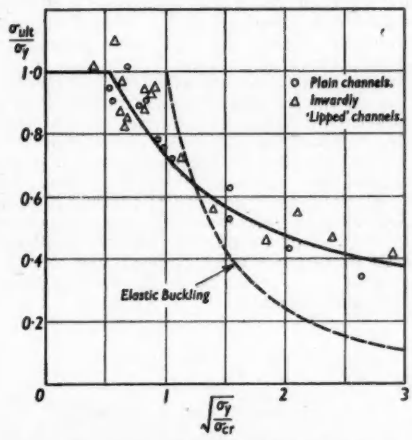


Fig. 17—Ultimate Strength of Thin-Walled Steel Channel Struts in Compression

The elastic critical stresses were computed from equation (4), the relevant values of θ_2 being taken from Figs. 7 and 9.

The test results are analysed in the form shown in Fig. 17. It is apparent that the yield stress is never fully attained over the whole cross section of the strut except for the stockiest types of channels. At the remote end of the test range the channels may be loaded to more than three times the elastic buckling stress before final collapse is brought about. An empirical curve which defines the test results is

$$\frac{\sigma_{ult}}{\sigma_y}=0\cdot724\left(\frac{\sigma_{cr}}{\sigma_y}\right)^{0\cdot3} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

which is valid in the range $0\cdot6<\sqrt{\sigma_y/\sigma_{cr}}<3\cdot0$. Equation (9) is compared with the tests of Sechler[4] and Winter[6] in Fig. 18. There is good agreement between the three curves. There are essentially two important loading conditions for a thin-walled steel strut: initially, a buckled condition in which there may be moderately large waving deflections in the web and flanges, not accompanied by an immediate collapse of the strut. Ultimate failure may occur at a considerably later stage. The critical stress and the ultimate stress are properties of the channel as a whole and not of any one component plate or any other. Critical stresses are defined by an equation of the type (4); due allowance should be made for a transition into the range of yielding. The ultimate stresses are defined by an equation of the type (9), the form of which is in good agreement with relevant tests by other investigators.

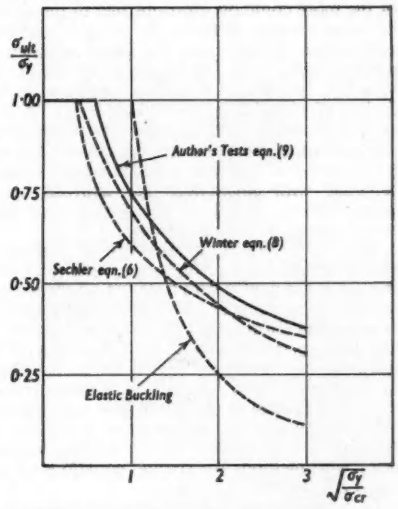


Fig. 18—Comparison of Ultimate Strengths of Structural Sections and Single Plates

TABLE I.—*Compression Tests on Plain Channels*

	Dimensions Web	Flange	Thick.	Number of compression tests	Young's modulus E	Compression yield stress σ_y	Ultimate stress σ_{ult}	$\frac{\sigma_{ult}}{\sigma_y}$	$\sqrt{\frac{\sigma_y}{\sigma_{cr}}}$
	in	in	in		Tons/sq in	Tons/sq in	Tons/sq in		
1	2	×2	×0·128	5	13,700	22·0	22·2	1·01	0·71
2	2	×1½	×0·128	5	13,100	24·2	22·1	0·91	0·57
3	1½	×1½	×0·064	8	13,500	18·6	17·1	0·92	0·83
4	1½	×1½	×0·064	10	13,300	20·8	15·0	0·72	1·05
5	1½	×1½	×0·036	9	12,800	19·9	12·6	0·63	1·56
6	1	×1	×0·048	8	12,700	21·8	16·3	0·75	0·98
7	1	× ½	×0·036	7	12,700	19·3	15·0	0·78	0·93
8	½	× ½	×0·080	8	13,700	26·6	25·2	0·95	0·55
9	4	×2	×0·128	4	13,300	21·2	19·2	0·91	0·77
10	4	×2	×0·048	3	13,200	11·9	6·26	0·53	1·54
11	6	×2	×0·048	3	11,900	11·9	5·25	0·44	2·04
12	8	×2	×0·048	3	12,600	13·0	4·35	0·34	2·64

TABLE II.—*Compression Tests on Inwardly "Lipped" Channels*

	Dimensions Web	Flange	Lip	Thick	Number of compression tests	Young's modulus E	Compression yield stress σ_y	Ultimate stress σ_{ult}	$\frac{\sigma_{ult}}{\sigma_y}$	$\sqrt{\frac{\sigma_y}{\sigma_{cr}}}$
	in	in	in	in		Tons/sq in	Tons/sq in	Tons/sq in		
1	6	×2	× ½	×0·048	7	13,500	19·0	10·8	0·57	2·09
2	5⅛	×2½	× 1	×0·116	4	13,200	17·8	16·7	0·94	0·85
3	5	×2½	× ½	×0·080	5	13,000	19·0	13·6	0·72	1·13
4	4	×2½	× ½	×0·080	5	11,900	15·9	15·3	0·96	0·88
5	3½	×2	× ½	×0·080	5	13,300	19·7	17·8	0·90	0·81
6	4	×1½	× ½	×0·128	5	12,800	20·6	22·4	1·09	0·59
7	3	×1½	× ½	×0·128	7	12,700	21·0	21·2	1·01	0·45
8	2½	×1	× ½	×0·064	6	13,200	21·2	19·0	0·90	0·78
9	2½	×1	× ½	×0·080	7	13,200	21·4	20·7	0·97	0·64
10	1½	× ¾	× ½	×0·048	6	13,200	22·5	18·7	0·87	0·68
11	1½	×1	× ½	×0·048	11	14,100	24·4	21·8	0·89	0·63
12	10	×3½	× ½	×0·048	3	12,400	11·9	4·85	0·41	2·88
13	8	×4	× ½	×0·048	3	12,100	12·1	5·52	0·46	2·40
14	6	×4	× ½	×0·048	3	12,500	12·4	5·67	0·46	1·83
15	4	×4	× ½	×0·048	3	10,900	11·9	6·65	0·56	1·46
16	2	×2	× ½	×0·048	3	13,800	12·5	10·50	0·84	0·66

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Analysers and Computers for Electrical Systems

A VACATION school on analysers and computers for electrical systems was held in the Electrical Engineering Department of Imperial College, London University, from July 13th to 17th. It was attended by some sixty engineers from industry, the British Electricity Authority, research associations, technical colleges and the universities. The purpose of the school was to encourage the wider use by electrical engineers of analysers and computers for solving the problems that arise in electrical machines, electrical control systems and power networks.

An opening address was given by Mr. F. J. Lane, Transmission Design Engineer to the British Electricity Authority, who referred to the continuing development of more accurate methods of calculating the design and performance of electrical systems. In the first lecture, Mr. B. Adkins, of Imperial College, described the course as an opportunity for electrical engineers to review recent improvements in the methods available for the solution of numerical problems with the aid of computers, analysers and models. He went on to discuss electrical machine problems, grouping them as design calculations and performance calculations, each group comprising routine calculations and research investigations, and showed some examples of each kind. In the following lecture, Dr. J. R. Mortlock, of the British Thomson-Houston Company Ltd., introduced some of the more common problems met in the design of power systems, showing the types of equation encountered in each and the usual methods of solving them. The third lecture, by Dr. J. H. Westcott, of Imperial College, dealt with the design of closed-loop control systems. A discussion of steady state calculations and graphical methods using harmonic responses was followed by a survey of methods of estimating transient response with suggestions for applying more comprehensive criteria to the performance and, hence, design, of control systems.

Dr. W. J. Gibbs, of the British Thomson-Houston Company, Rugby, opened the next section of the course with a lecture on the mathematics of the problems. He showed that problems first require formulation by the specification of an ideal system which can be represented in mathematical terms, and then reviewed the kinds of calculation often required. He demonstrated that matrices can assist the orderly arrangement and manipulation of performance equations of all kinds of system. The remaining lectures dealt with methods for solving equations of the kinds decribed by Dr. Gibbs.

In a lecture on "Systematic Computation," Mr. M. W. Humphrey Davies, of Imperial College, put forward suggestions for processes intermediate between simple slide-rule calculations and the complex methods used in automatic computers. After surveying existing hand-operated calculating machines, he demonstrated a convenient method for the solution of sets of linear simultaneous equations, and described an improved design of semi-automatic machine that is being constructed at Imperial College and is intended for handling two-dimensional quantities. He concluded by suggesting that semi-automatic machines might be specially suitable for many routine calculations.

On the Tuesday evening members of the school visited the laboratories at Imperial College and saw the automatic digital computers constructed by Dr. Tocher in the Mathematics Department, and a transformer-analogue analyser, a semi-automatic decimal computer for complex quantities, and other analogue devices in the Electrical Engineering Department. Wednesday was spent at the National Physical Laboratory seeing the automatic computer. "A.C.E.," the analogue differential analyser and the punched-card tabulating equipment in the Mathematics Divisions, and an analogue device for the design of control systems in the Servo-Mechanisms Laboratory.

Dr. J. M. Bennett, of Ferranti, Ltd., described several kinds of automatic digital computer and discussed the advantages of their rapidity and accuracy in dealing with different kinds of engineering problems. The lecture concluded with details of the method of handling typical problems. Mr. L. Gosland, of the Electrical Research Association, in a lecture on "Analogue Analysers," gave an intensive survey of analogue computers, network analysers, models and simulators giving examples of their application to practical problems.

The final lecture, by Dr. G. R. Slemon, of Imperial College, was concerned with the solution of non-linear problems, and was confined to the two methods of considerable generality, namely, numerical or step-by-step methods, and approximate steady-state methods using modified linear techniques. Finite difference methods were described for the solution of first-order, simultaneous and higher-order differential equations with variable parameters. Dr. Slemon then explained his "fundamental frequency" approach to steady-state non-linear circuits, and showed how this could be applied to both power-frequency and stability problems. Finally, adaptations of mathematical, graphical and other techniques for use with the fundamental-frequency method were surveyed.

The discussions during the course suggested that there would be considerable demand for the facilities of automatic computing machines as they become available and that there was scope for improvements in desk machines. It was felt that a desk computer with a trained operator would be a useful adjunct to many engineering offices, but that analogue rather than digital devices would often be preferred by engineers because explicit mathematical formulation of the problem was unnecessary, and because the former devices were frequently analogous to the physical system ; they had the added advantage, in power network and similar problems, that the general behaviour of the system can be observed directly. Such devices made it possible for the engineer to solve his own problems with only occasional assistance from a mathematician, and this was thought to be preferable to the use of external computing services.

Systematic Road Accident Investigation

THERE has been submitted to the Minister of Transport by the Engineers' Guild a proposal for a systematic investigation of road accidents. Below we give particulars in outline of the proposals.

In each county and county borough there should be a suitably qualified engineer appointed as accident investigation engineer, whose sole task would be to examine, in consultation with the police, the records of all fatal and other serious accidents on classified roads (including trunk roads).

The accident investigation engineer would be under the direction of the county or borough engineer, but the appointment would be subject to the approval of the Minister of Transport, who should contribute a grant of 50 per cent of the officer's salary.

The accident investigation engineer would inspect the site of every serious accident, the cause of which was not self-evident from the police report, in company, where possible, with the police officer making the original report. A copy of the report of each such accident on trunk roads would be sent with his own opinion of the cause to the divisional road engineer.

The accident investigation engineer would prepare each month, for submission to the divisional road engineer, a list of accidents which had occurred on each classified and trunk road, stating for each accident whether his investigations had shown one or more of the following factors to have contributed to the cause :—

(1) Vertical or horizontal alignment of road.
(2) Insufficient width of carriageway.
(3) Incorrect cross-fall of carriageway (i.e. lack of superelevation or excessive camber).
(4) Lack of or incorrect lane markings.
(5) Lack of definition of edge of carriageway.
(6) Ribbon development or uncontrolled access (e.g. waiting vehicles, vehicles emerging from private accesses).
(7) Lack of parking or lay-by space.
(8) Defective road junction layout.
(9) Defective or insufficient warning, direction or mandatory signs or traffic control signals.
(10) Insufficient or badly designed or sited street lighting.
(11) Lit or unlit advertisements and signs confusing to drivers.
(12) Insufficient or inadequate facilities for pedestrians crossing the carriageway.
(13) Surface conditions of carriageway.
(14) Mechanical defect in vehicle.
(15) Defective lighting on vehicle.
(16) Physical disability of driver.
(17) Physical failure of driver.
(18) Error of judgment by driver or pedestrian.
(19) Other causes.

In the case of factors (1) to (13) being present he would give the approximate cost of remedying the road defect and state whether a major improvement would be involved or whether the work could be carried out as a minor improvement or under maintenance. Those cases where a public inquiry was recommended would be indicated.

Where in the opinion of the county or borough engineer—in the case of other than trunk roads—a public inquiry is desirable to obtain facts and evidence not readily obtainable by the accident investigation engineer under sub-section (2) of section 23 of the Road Traffic Act, 1930, the County or County Borough Council would notify the divisional road engineer requesting arrangements to be made accordingly. In the case of accidents on trunk roads it would be the responsibility of the divisional road engineer to advise the Minister when a public inquiry was desirable.

An engineer should be assigned to work under each divisional road engineer of the Ministry of Transport as a divisional accident investigation engineer, and this officer should be responsible for co-ordinating, through the county or borough engineers, the work of local accident investigation engineers.

The divisional accident investigation engineer would collate the information obtained from the local accident investigation engineers' reports for both county and trunk roads in his division, and would draw the attention of the divisional road engineer to :

(*a*) General trends and inferences to be drawn from causes of accidents ;

(*b*) Lengths of roads and junctions on which road conditions are the main cause of accidents ;

(*c*) Prevalent failures of road signs, signals, lighting and vehicle mechanism and equipment.

There should be set up at the headquarters of the Ministry of Transport a road accident inspectorate under the chief engineer.

This would include engineers with experience in holding public inquiries and considerable experience of highway and traffic matters generally. They would be responsible for holding the necessary public inquiries and, under the chief engineer, for the general direction of the campaign to ascertain from the systematic investigation of individual accidents the main causes of accidents, and the preparation of :

(*a*) Recommendations for the mechanical improvement of vehicles and their equipment.

(*b*) Recommendations for improvement of road signs, signals, equipment and standards, street lighting and the illumination of road signs.

(*c*) A national priority list of road improvements indicated by the results of accident investigation to be of first importance in the interests of safety.

(*d*) Additions or amendments to the Highway Code.

(*e*) Matters calling for new legislation in the interests of safety.

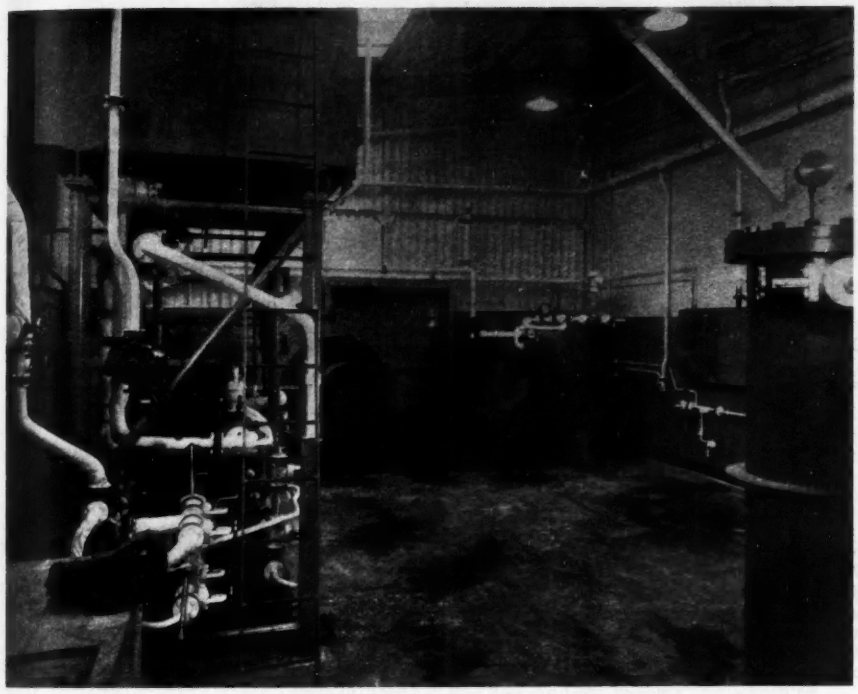
(*f*) Any other recommendations which they consider would reduce the accident rate on highways.

This inspectorate should have available to sit with them as assessors at public inquiries psychologists or medical officers of the Ministry of Health when they considered the circumstances of a case rendered this desirable. Their reports on these public inquiries should be published by H.M. Stationery Office, in the same way as railway accident reports. The inspectorate would prepare annually a report to be included in the Road Fund report, or published as separate publication, as the Minister thought fit.

Development of Oil Fuel Burning Equipment

RESEARCH into the combustion of fuel oils has been steadily increasing, and to deal with the many and varied problems, White's Marine Engineering Company, Ltd., has recently completed a new test house at Hebburn-on-Tyne to house the research and development department. The building, of which we show a general view, has a floor area of 2000 square feet and contains a test furnace which will be capable eventually of absorbing 42,000,000 B.Th.U. per hour and a shell boiler capable of absorbing 19,000,000 B.Th.U. per hour. Over the last twenty years most of the research has been concerned with the atomisation of oil by all the basic forms of sprayer, so that there is a large amount of data available on their spray characteristics. Therefore it is considered that, given reasonable manufacturing facilities, the production of a good oil sprayer should not present difficulties. However the problem of the design and development of air registers remains, since very little data exist and design is usually based on experience by steam or electricity. Ancillary services provided for the furnace include a 3in town gas main for testing oil/gas burners, a 2in compressed air main with receiver, a 1in fresh water main and a gravity tank for gas oil. When extended and fitted with water cooling coils the furnace will be capable of testing burners having a capacity of 1 ton of oil per hour.

Combustion air is delivered to the furnace by a Davidson fan at a pressure of 20in W.G., almost all of which is available for discharge through the register, and this means that air at velocities of over 17,500ft per minute is available for mixing with the oil spray With these facilities it is hoped to develop pressure jet burners obtaining CO_2 figures of over 14 per cent from full to half load. The Scotch marine boiler is used for the development of natural draught registers and for the testing of blast burners. During the latest tests on natural draught 13 per cent CO_2 has been obtained with a draught loss of 0·25in W.G. through the



Test House for Oil Burning Equipment

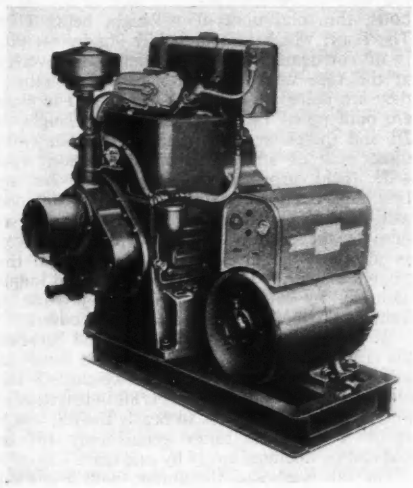
and perfected by trial and error. This lack of knowledge called for an extensive programme of research, and so the facilities in the new test house have been developed on the air flow side of oil burner design.

The test furnace can at present take burners of up to 800 lb per hour capacity and is fitted with a pumping, heating and filtering set capable of delivering 1·5 tons of oil at 300 deg. Fah. and 450 lb per square inch gauge, which was adopted as being the maximum economical oil pressure. Any increase in combustion efficiency resulting from a higher pressure is offset by the higher pump energy required. A better approach to improved efficiency is by attention to the mixing of oil and air, since a reduction in oil consumption results from reducing excess air to a minimum. Another factor militating against higher oil pressures is the greater danger of leakage, and the higher cost of the installation due to the need for increased scantlings of the fittings. Pumping of the oil up to the maximum pressure is done in two stages, first to 200 lb per square inch gauge and then to 450 lb per square inch gauge, while the heating, which is thermostatically controlled, can be either register. The degree of atomisation and mixing with combustion air for most air or steam burners cannot always be gauged in tests, due to high furnace temperature, and so a range of low-pressure air atomising oil burners are being tested for efficiency in a "cold" combustion chamber. A Radiovisor electronic smoke indicator is used to obtain records of the efficiency of combustion.

Research on oil burners is now proceeding and includes work on high-pressure oil burning equipment, concerning which a study is being made of the aerodynamics affecting air register design. Running parallel with this work is the problem of register design for spill burners, which is made complex by the wide variation in their capacity. Another series of tests concerns remote-controlled oil burners for lighting up pulverised fuel flames in power station boilers, the control system at present under test is one in which the operator on the floor of the station can flash up a boiler by a press button and where the sprayer is scavenged by compressed air after shut down. Three forms of ignition equipment are under survey, including the resistance coil, a 10,000V spark and a "High Energy" igniter. Low-pressure air atomising oil burners are included in the programme, and that under test is controlled by a single lever. At present a turn down ratio of 4 : 1 is being obtained, but an attempt is being made to increase this ratio to 6 : 1. In addition to the above programme investigations are being carried out into the burning of liquid fuel in combustion chambers containing a high-pressure atmosphere, electronically controlled, fully automatic oily water separators and a variety of heat exchangers, while a separate department is concerned with research on mechanical oil seals, plastic conveyor rollers and rubber bonding problems.

A 1·25 kW Diesel Generating Plant

A SMALL diesel-driven generating plant, seen in our illustration, has recently been introduced by Dale Electric (Yorkshire), Ltd., for the purpose of meeting a demand for such a unit which is reasonable in first cost and has low running and maintenance charges. This is a 1250W a.c. unit with remote control and is suitable for small farms, cottages and mobile workshops. The unit is mounted on a base-plate constructed from heavy rolled steel channels with slide rails built in and complete with belt adjusters and holding-down bolts. The self-excited, drip-proof, fan-ventilated generator is fitted with heavy-duty ball bearings and is of self-regulating design. It is driven by multiple vee ropes from the engine and has an output



1·25 kW Diesel Driven Generating Set

of 1250W at any standard a.c. voltage. Contactors are fitted inside the switch box, which has a charge ammeter, charge circuit fuse and push buttons, for semi-automatic operation, and there is also a connection block for the outgoing cables to load.

A Petter "P.A.Z.I." air-cooled, single-cylinder, direct-injection diesel engine, which develops 2½ b.h.p. at 1500 r.p.m., and has a bore and stroke of 3in, forms the power unit. It has a cast iron crankcase with integrally cast feet for base mounting, and the lower part forms a wet sump. The aluminium alloy piston has three compression rings and two slotted scraper rings, and a fully floating gudgeon pin, and the forged steel "H" section connecting-rod carries plain big- and small-end bearings. A bronze bush is used at the small end and the big-end bearing is of copper-lead steel backed, while the main bearings are steel-backed white-metal-lined precision bushes. Special cast iron is used for the deep-finned cylinder and the cylinder head, which is also deeply finned to give adequate heat dissipation, carries the rocker box enclosing the pressure-lubricated rocker gear. The push-rods are enclosed within the cylinder wall and the cylinder and cylinder head are held by through bolts to the crankcase.

A tank mounted on the engine holds 1 gallon of fuel, which is gravity fed to a Bryce fuel

pump located on the top of the timing gear cover and actuated by a cam on the front of the camshaft gear wheel. A fabric fuel filter is incorporated in the fuel system and the spill timing is adjusted by means of shims under the fuel pump. A plunger pump actuated by an eccentric on the camshaft supplies oil under pressure to the bearings and rocker gear, while the cylinder and camshaft are splash lubricated. Included in the equipment is an oil bath air cleaner and a pepper pot silencer and a 12V, nine-plate Exide battery is provided for starting. The shipping specification of the complete unit is : length 32in., width 24in, height 30in, gross weight 460 lb, and net weight 370 lb.

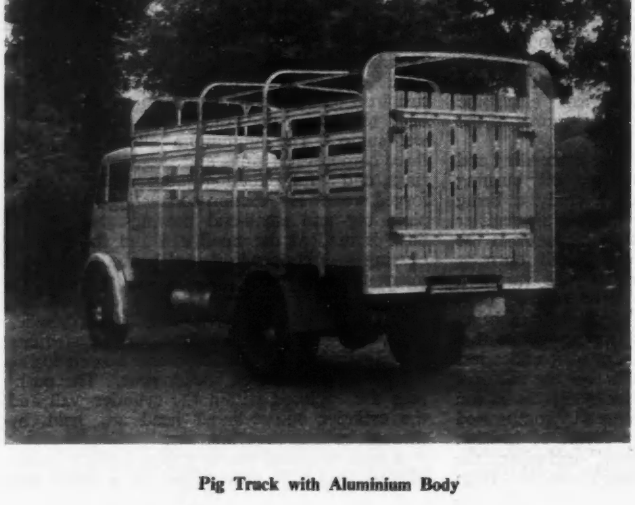
An Aluminium Pig Truck

A PIG truck with an aluminium body designed and built by Warmley Motor Body Works, of Warmley, near Bristol, for Falmouth Transport, Ltd., is illustrated below. To provide the desired capacity a floor area of about 100 square feet was required and a body of this size would normally bring the unladen weight of the vehicle to over 3 tons. As a 20 m.p.h. speed limit was unacceptable, the obvious way of attaining a light but strong body was to build it in aluminium alloys. Materials supplied by Northern Aluminium Company, Ltd., were used, the alloys chosen being Noral 51S for the sections and Noral M57S for the sheet.

The chassis is an Albion ST.37.N. Seven cross-bearers of 3·9in by 1·5in channel section are supported by 7in by 2in channels laid along the main chassis members and secured by " U "-bolts, the total under-floor height being 11in. The floor, which measures 14ft 9in by 6ft 9in, is of corrugated sections arranged to overlap at the top, where they are riveted together ; they are bolted to the cross-bearers. The sides are built up of 14 S.W.G. sheet to a height of 2ft and thereafter to a total of 4ft 6in, with three rails of strong corrugated section 4⅜in wide, held together by six vertical 2in by 1½in angle sections. Top-hat sections, stiffened with 16 S.W.G. strip riveted across the open sides of the section are carried over the top, as also are the angle framing sections at the front and rear. They are interconnected longitudinally by a central runner to provide a framework which supports a tarpaulin cover.

An ingenious folding ramp is stowed between the chassis members where it is locked firmly in such a manner as to take the weight off the runners and prevent rattle. It is 8ft in length and, when withdrawn, unfolds to nearly the full width of the body. The ramp weighs only 167 lb and can be operated easily by one man.

The cab is also of aluminium, with a riveted framework of channel sections to which the skin, with welded seams, is attached by riveting. The body weighs 9 cwt, including the ramp and gates, and the cab weighs 2¾ cwt, which brings the tare of the whole vehicle within the 3-ton limit with 1¼ cwt to spare. It is estimated that an equivalent body built in timber and steel would have weighed 11 cwt more.



Pig Truck with Aluminium Body

Two Receiver Bays at Crowsley Park

Receivers for B.B.C. Monitoring Service

OUR illustration shows part of an installation of twenty-eight new receivers in the Crowsley Park receiving station which forms part of the British Broadcasting Corporation's monitoring service. It may be recalled that the B.B.C. monitoring service was developed during the war to pick up, for intelligence purposes, broadcast transmissions from foreign countries, and that the service was retained after the war as a source of information for B.B.C. news bulletins and Press information as well as for the benefit of Government departments. The main monitoring facilities and administration of the service are at Caversham Park, Reading, and there is a remote engineering interception station at Crowsley Park, 3½ miles to the north, in an electrically quiet area, which is suitable for an extensive directional aerial system.

The new receiver (the " BRT 400 D "), as supplied by the General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2, is a fourteen-valve superheterodyne set with a frequency range, modified to suit B.B.C. requirements, of 150 to 385 kc/s and 0·51–30·0 Mc/s in six bands. The input impedance is 75 ohms on all bands. Selectivity has also been adjusted to suit the B.B.C. There are six switched bandwidths, the overall bandwidths for 6 db attenuation being 5·5 kc/s, 9·0 kc/s, 13·0 kc/s for telephony, and 0·5 kc/s, 1·0 kc/s and 2·0 kc/s for telegraphy, the last three positions with a crystal filter in circuit between the mixer and i.f. amplifier. By operation of the filter phasing control an interfering signal only 1 kc/s away from a wanted signal can be attenuated by at least 45 db. The receiver is thus designed to cater for the extreme requirements of high-quality telephony and long-distance telegraphy reception. A useful innovation is the provision of an outlet from the i.f. amplifier at suitable level and impedance (5 millivolts across 100 ohms) at a coaxial socket at the rear of the receiver. This allows the equipment to be used for frequency shift keying.

In the new receivers the local oscillator frequency stability has been improved. All the receivers were subjected to an extended drift test, the specification requiring that oscillator frequency drift should not exceed 5 kc/s measured at 29 Mc/s, 3 kc/s measured at 19 Mc/s, and 2 kc/s measured at 8 and 3 Mc/s. In practice, when the receivers reach a stable operating temperature, drift figures much lower than these are normally obtained. Local oscillator radiation, which has also been improved, is less than 250 microvolts. Ten of the receivers installed by the B.B.C. at Crowsley have a built-in crystal calibrator which gives pips at 500 kc/s intervals and is operated by a push button on the front panel. All are fitted with chromium-plated " D " handles to facilitate their removal from their racks for servicing. Another improvement is the provision of a lock for the tuning control : the design of the locking mechanism prevents any movement of the tuning control once the lock is applied.

The receivers are installed in a number of bays arranged on both sides of a central jacking switch board. Two of these receiver bays can be seen in the accompanying photograph which shows, above the receivers, the aerial selector switch panels and, below the receivers, the audio switch panels, jackfields and peak programme meter.

Two receivers, similar in design to those described above, have been installed as part of the supervisory console in the main listening room of the B.B.C. monitoring service at Caversham Park, Reading.

A COAL-CUTTING ATTACHMENT FOR DRILLS.—A note from the National Coal Board states that Mr. G. Paton, chief mechanical and electrical engineer, of Knockshinnoch Castle Colliery, Scotland, has produced an attachment which enables an ordinary electric drill to be used as a coal-cutter. For this purpose a reciprocating gear adapted to an electric drill drives a boring bar 4ft 7in long and fitted with cutter tools. Mounted on a standard, the machine pivots to give a vertical shear in the coal face 3ft deep by 2½in wide ; the reciprocating gear provides the action necessary to clear running. The device has been designed to fit the " Huwood " " HCS/N3 " or a Siemens Schuckert " E47/11 " drill. A standard drill panel controls the machine. The device is stated to be particularly suitable for work in steeply inclined seams, where it can be used for vertical undercutting as well as shearing.

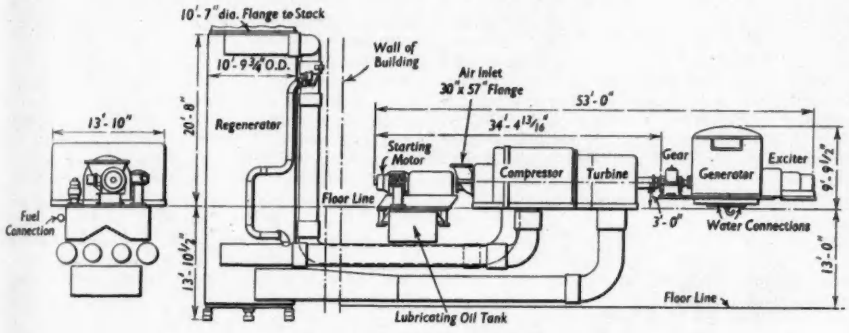
American Engineering News

(By Our American Correspondent)

A Gas Turbine Generator Power Station in Texas

The recently completed Dixon Street power station of the Texas Power and Light Company, at Gainesville, Texas, is a good example of the growing and successful applications which comparatively small, standardised gas turbine generator sets are finding as stand-by units in some of the more remote parts of the United States. Gainesville is situated in North-Central Texas, which is vulnerable to severe and frequent ice storms. Since it was necessary to assure Gainesville continued electric power service in the event of a crippling ice storm, the Dixon Street power station was built there. This plant consists of a 1MW dual-fuel engine and a 3·5MW General Electric regenerative gas turbine driving a 5000kVA generator. The selection of these two generating units was based on an economic study in which steam units, and various kinds and sizes of internal combustion units were considered. The factors considered included fixed charges on investments, operating costs, maintenance, reliability, availabiiity and starting time.

The gas turbine went into service in May, 1952, and has operated more than 1000 hours, being used almost daily in peak load service as needed. The installation is said to have a thermal efficiency of 23 per cent, based on the higher calorific value of the natural gas fuel. Both machines in the station can be started quickly in case of transmission line failure, but it has been the practice to run the gas turbine when ice storms are expected. The gas turbine and the diesel engine have been arranged side by side in a 50ft by 75ft brick building, and there is ample room around each machine for accessibility and servicing. The gas turbine is served by an overhead crane of 15 tons capacity, with the crane rails parallel to the length of the machines.



Outline of Gas Turbine Installation

As shown in the accompanying illustration, the gas turbine, generator and regenerator are all mounted in line, the regenerator being outside the building wall. All of the hot gas piping between the regenerator and the gas turbine is arranged under the foundation and under the operating floor. The oil tank is installed under the inlet end of the compressor between the gas turbine and the regenerator. The top of the oil tank is flush with the operating floor and forms a mounting for the oil coolers and auxiliary and emergency lubricating oil pumps. The fuel gas compressor, which is situated in the station yard, receives natural gas at the supply pressure of 25 lb to 40 lb per square inch gauge, and compresses it to a pressure of 160 lb per square inch gauge, which is required by the gas turbine fuel system. The compressor is a rotary, horizontal, two-stage machine driven by a 200 h.p. electric motor and delivers 1090 cubic feet per minute at a suction pressure of 25 lb per square inch gauge.

A cooling tower, which is situated in the station yard, dissipates the heat rejected by the turbine lubricating oil system and the turbine cooling water system. It has a cooling range of 105 deg. to 95 deg. Fah. at 78 deg. Fah. on the wet bulb thermometer, based on a capacity of 500 U.S. gallons per minute. Also placed in the station yard is the turbine inlet air washer or evaporative cooler. It is equipped with wet-cell glass filters, an internal water spray system, and spray eliminator plates. The air washer cools and humidifies the air used by the gas turbine. The evaporative cooling aspect of the unit results in a drop in inlet air temperature of about 20 deg. Fah. when the dry bulb thermometer is at 100 deg. Fah. and the wet bulb at 78 deg. Fah. The increase in power output due to this 20 deg. temperature drop is about 450kW.

The gas turbine is supported on a concrete foundation consisting of concrete beams supported on pillars, that span the pit in which is situated the exhaust duct and the hot gas piping leading to and from the regenerator. The operating floor is below the centre line of the rotating machine elements, and the base of the regenerator is approximately 14ft below the operating floor line. All the piping and ducting between the turbine and the regenerator is so arranged with expansion joints and hangers that no expansion loads or gas pressure forces, which might cause misalignment, are exerted on the machine. The regenerator is a vertical unit of shell-and-tube design, incorporating counterflow of gases. Compressor discharge air enters the top of the regenerator and flows outside the tubes to the bottom, where it is piped to the combustion chambers on the gas turbine. The turbine exhaust gases are fed through ducts to the bottom of the regenerator below the tube sheet, through the tubes, and escape through the stack which is mounted on the regenerator. There are 5100 tubes, each 1¼in in diameter and 28ft long, in the heat exchanger, resulting in a total surface area of 46,000 square feet. The regenerator has a design effectiveness of 80 per cent, and its pressure drop amounts to 5 per cent of the absolute pressure.

The gas turbine is a two-shaft machine with a load or low-pressure turbine mounted in the same casing, but completely separate from the high-pressure turbine which drives only the fourteen-stage axial-flow compressor. The inlet air is compressed to a pressure ratio of 5·5 to 1 and is ducted from the discharge casing to the regenerator. The heated h.p. air is then fed back to the machine to the vertical combustion air manifolds from which it enters the six combustion chambers. Fuel is injected and burned in the combustion chambers, and the hot gas passes through the h.p. nozzle and turbine. The gases leaving the h.p. turbine flow along the axial gas path into the l.p. turbine, which drives the load. Then the gases escape through the exhaust hood, the exhaust duct, and through the regenerator to atmosphere. The nozzles ahead of the l.p. turbine are variable in area, a detail which is said to limit overspeeds in case of loss of load, to give a better heat rate at partial load, increase the machine power output at high ambient temperatures, to reduce starting power requirements and to facilitate running at no load while synchronising.

Some difficulties have been experienced with the gas turbine since it was installed last year. The variable turbine nozzles showed some tendency to stick and required the reworking of the parts involved to eliminate the binding tendency. A blow-off valve was added to the h.p. side of the regenerator to limit the l.p. turbine and generator overspeed to a safe value if high load were to be dropped and the second-stage nozzles did not open fully. There have been several points of oil leakage from the machine which have been remedied by the replacement of some bearing seals during a recent overhaul. The regenerator has given some evidence of distress at the lower tube sheet, and it is planned to install an expansion joint in the regenerator shell during a forthcoming overhaul in order to reduce the stresses resulting from the severe differential expansion between the tubes and the shell during operation.

Starting, stopping and operating the gas turbine has been found relatively simple and can be easily accomplished by one man. On starting, the auxiliaries are manually started by operating the individual starters in the control cabinet. Then the machine can be brought to any one of five conditions when the starting button is pushed, depending on the position of the operation selector switch. The positions on the switch are : " Off," " Crank," " Fire," " Speed Control " and " Automatic." With the selector on " Automatic," speed and load are controlled from the generator panel, on " Speed Control " these functions are controlled from the gas turbine panel. The starting sequence is automatically controlled up to the selected condition. The machine is cranked, purged, fired, accelerated and brought to speed with the aid of the governor when the selector switch is in either the " Speed Control " or " Automatic " position. The starting motor is shut down and declutched from the turbine shaft and the auxiliary oil pump is shut down automatically in the starting sequence. After being brought to speed, the machine is synchronised and put on the line. During operation, the governor controls the fuel supply to hold the set speed and load, subject, however, to an overriding exhaust temperature limit which will limit the fuel feed to prevent exceeding the set exhaust temperature. In addition to the normal control, there are over-speed trips in each turbine shaft and an exhaust temperature trip which is set somewhat above the normal exhaust temperature limit. Low lubricating oil pressure, high lubricating oil temperature, or high turbine cooling water temperature will also trip the machine off the line.

The power station operates on a standby basis ; therefore, only a minimum operating staff is required. Apart from the operation of the power plant, it is, however, necessary to have someone on duty at the station at all times to handle the dispatching by wireless of the distribution, maintenance and service personnel within a 30 mile radius of the station and to act as an emergency relay station for the main northern dispatching point of the power company at Sherman, Texas. To accomplish this, a five-man team was established, consisting of a chief engineer to act as general supervisor of the station staff, three regular shift operators and a relief operator to maintain the twenty-four-hour requirements for the seven-day week. Each operator puts in one extra eight hour day per month to complete the schedule.

A Ceramic Coating for Low-Alloy Steel Jet Engine Parts

In a paper presented at the recent spring meeting of the American Society of Mechanical Engineers, J. V. Long, of the Solar Aircraft Company, San Diego, California, gave an account of applications which the " Solaramic " coating process, developed by that company, is finding in the protection of jet engine components made of low-alloy steels. A " Solaramic " coating is a thin, vitreous or semi-mat ceramic coating which is bonded tightly to the surface of the metal, sealing it against the effects of high temperatures and combustion products. The smooth surface provided by the coating offers a minimum resistance to the flow of gases which, combined with the elimination of oxidation, mitigates hot spots and protects the parent metal against cracking and warping under high-temperature operating conditions. Because of its extreme flexibility and bonding strength, such a coating can be used to protect metal sheet as thin as 0·001in. The coating covers various kinds of welds, materials and alloys in different thickness gauges used in the manufacture of a

single part, thus allowing the coating of standard parts without design changes.

In aircraft engineering, jet engine components that have been coated to date include combustion chamber liners, transition liners, cross ignition tubes and exhaust cones. For piston engine aircraft, turbo-supercharger nozzle boxes, turbo-hoods and exhaust manifolds have been coated.

The production of the coating materials starts with the careful blending of the raw materials consisting of metal oxides and fluxing agents. The blended mix is then placed in a rotary furnace and smelted at temperatures ranging between 2200 deg. and 2700 deg. Fah. During this period the components of the mixture fuse into a homogeneous molten liquid. This melt is poured into cold water ,where it is quickly chilled. The quenching operation produces a material having an appearance resembling that of crushed glass, called frit. The rapid cooling of the frit produces internal strains in the glass-like material and facilitates its reduction to a fine powder in subsequent milling operations. After quenching, the frit is placed in a drying chamber, where all excess water is removed by evaporation. It is then ready for grinding in a ball mill, where the frit particles are crushed. To the mill is also added a quantity of water, clay and other binding agents, known as mill additions. After the aggregate has been reduced in particle size to the requisite fineness and uniformity it is a rather viscous liquid called slip. The ceramic slip may be thickened or thinned as desired for the actual coating operation.

Cleanliness is an important factor in the successful application of the ceramic coatings. All traces of welding flux, pickling films and heat-treatment scale must be removed from the metal surfaces to be coated. Grease, oil, and even finger prints are detrimental to successful coatings. To remove grease and other organic impurities a detergent degreasing bath is used. After thorough rinsing an acid etch is often applied by immersing the part in a nitric and hydro-fluoric acid bath. Following the acid etch, high-pressure water jets are used to rinse the part and remove all traces of the acid. The part is then dried and is ready for coating. Following the degreasing operations a part may alternatively be sandblasted. Both sandblasting and acid etching produce a roughened surface, which improves the bond strength between the applied coating and the metal. Care must be used in the sandblasting operation not to over-erode the metal to a thinness under drawing tolerance. After sandblasting, the part is either washed down and dried or blown dust-free with compressed air and is then ready for coating.

Either spraying or dipping may be used to coat parts, and in most cases a single coating is sufficient. For some parts dip coating is more rapid and economical than spraying, and eliminates the need for spray equipment and booths. However, if the parts are of complex geometry and tolerances are small, the spray application is preferred. At the spray booth the part is coated in a manner similar to normal spray painting procedure. The coating should be evenly applied, and in most cases should be between 0·001in and 0·002in thick. The coated part is placed in a drying cabinet until the coating is dry. Since the unfired coating, called a bisque, may be damaged by rubbing action before firing, careful handling at this stage is essential to avoid marring the prefired parts. When dry, the coated parts are attached to racks and placed in a furnace, where they are subjected to a firing temperature between 1500 deg. and 2000 deg. Fah. for a predetermined period of time, from ten to thirty minutes, depending on the size and nature of the part. Upon removal they are allowed to cool and the finished coating is then ready for inspection.

A development programme in the field of ceramic coatings was initiated in 1942, when the American Government decided that exhaust manifolds for military aircraft could be fabricated of low-carbon steels protected with standard porcelain enamels. The Solar Aircraft Company was asked by the military to work out fabricating methods for mild steels and was successful in completing a number of mild steel manifolds, which were delivered to the U.S. Air Force for subsequent coating with porcelain enamel. After the war there was a growing demand for combustion chamber liners and other jet engine components, and, in the interest of conserving critical materials, the company began to investigate the substitution of coated mild steel liners for "Inconel" liners. An initial difficulty was encountered in firing the coating on certain large liners. At the firing temperature the mild steel had insufficient stability and the liners warped and sagged, so that the first liner to go into a performance test lasted just twelve hours before failure. It was then felt that if an alloy lower than "Inconel," but mechanically as strong, could be found, the deficiency in resistance to oxidation could be made up with high-temperature ceramic coatings. The next approach was a liner in which the inlet and outlet ends were fabricated of higher alloy, the body section being mild steel. Since the inlet is the cold end, the use of "Inconel" here would at first appear to be a waste of strategic material, but the added strength allowed the maker to hang the liner on the coating, and no furnace sag or warp occurred when firing.

Subsequently, considerable success was obtained in using a titanium-stabilised 18-8 stainless steel conforming to the American Iron and Steel Institute specification "Type 321." When protected with the ceramic coating, liners of "Type 321" material, in competition with "Inconel" liners, not only surpassed the standard service life, but were capable of further service after several of the "Inconel" liners had reached the failure point. So successful were the performance tests that the same material is now also being used in the manufacture of turbo-hoods for reciprocating engine turbo-superchargers. Another application where it has proved possible to save scarce materials was the turbo-supercharger nozzle box of aircraft engines. Here, a "Type 347" columbium-stabilised 18-8 stainless steel was replaced by the ceramic-coated "Type 321" material. The first experimental nozzle box units were coated and fired after finish machining, which caused a large amount of warping. It was therefore decided to coat and fire before finish machining, which enabled the tolerances involved to be met.

The author made it clear that, in his opinion, there was a large and growing field of application for ceramic-coated mild steel and low-alloy steel jet engine and reciprocating engine components, but that experience has shown that substitutions of higher alloy materials could only be successful if an appropriate redesign was developed on the basis of the properties of the substitute material.

Continental Engineering News

(By Our Continental Correspondent)

The Oued Tissemlalt Bridge, Algeria

As a result of the construction of the reservoir of Iril Emda, in Algeria, it has been necessary to build a highway bridge over the Oued Tissemlalt. The bridge is of reinforced concrete construction and accommodates a roadway 23ft wide and two footpaths each 5ft wide. The main structure consists of two twin arches with fixed ends, each of 215ft span and 49ft rise, with constant width and a depth of 3·6ft to 3·9ft. The foundations rest on sound rock at a depth of 13ft to 19½ft. The approaches, which are curved in plan (minimum radius 295ft) have ten spans at an average height of 33ft. The centering consisted entirely of steel tubing, with a height of 82ft from ground level to the crown of the arch.

Oil Refineries in Italy

Two new oil refineries are at present nearing completion in Italy. The Condor refinery, which will be shortly in service, is situated at Rho, near Milan, i.e. about 65 miles from the Mediterranean coast. The crude oil comes from Genoa, some 80 miles from the refinery. An oil dock has been built at Fegino, near Genoa, from which two pipelines will carry the oil to a tank farm having a capacity of some 100,000 cubic yards. The installation has a pumping capacity of 1300 cubic yards per hour. A buried steel pipe of 12in diameter traverses the Apennines mountains up to a height of 2600ft and leads to the refinery. The Condor refinery covers an area of 200 acres and comprises sixty-five storage tanks, an atmospheric distillation unit, a catalytic cracking plant, a gas separator, a boiler-house, &c. The annual capacity of this refinery will amount to about 1,500,000 tons.

Another new refinery, owned by the Sarom Company, is at Ravenna, on the banks of the Candiano maritime canal. Owing to the lack of suitable port facilities on the canal, a double pipeline, of steel construction, is to be built from the refinery to the sea, a distance of 2½ miles. Tankers will berth near a pumping station, erected on piles driven into the sea bed; then the crude oil will be delivered through the pipeline to the refinery. The annual capacity of the Ravenna refinery will amount to 1,500,000 tons.

An Oil Refinery at Antwerp

A Belgian affiliate of the Standard Oil Company is placing its new refinery at Antwerp on stream and expects it to reach capacity production very soon. The refinery is designed for a crude oil capacity of 25,000 barrels per day and will supply motor fuel and heating oils to the Benelux countries. It occupies a 190 acre site beside the Schelde River, and is being completed at a cost of 25,000,000 dollars (£9,000,000). Its construction was financed entirely by private capital and 85 per cent of its equipment was built by Belgian industry. It will employ about 350 Belgian workers. The plant installed includes a modern fluid catalytic cracking equipment, using processing techniques evolved by the Standard Oil Development Company, the central research affiliate of the group. By this process catalytic cracking and distillation operations are combined in one unit. Integral with the refinery are two tanker docks for unloading crude oil (coming from the Middle East). There are also three barge loading berths and facilities for direct delivery of bunker fuel oil to ships. Preparation of the refinery site and docks required the dredging of some 2,800,000 cubic yards of sand for use as fill, and the complete construction time was slightly more than two years.

Bridge Building in Finland

Two important bridges have recently been built in Finland. One of them a railway and highway bridge over the river Kemi, in Lapland, replaces a bridge destroyed during the war. A single track railway line crosses the bridge above the roadway; i.e. the cross section shows a railway above and a roadway below, the roadway being 20ft wide with a pavement 7ft wide outside the main girders at each side of the bridge. The three main openings are designed as continuous lattice trusses of 230ft, 232ft and 230ft spans. The approaches consist of two simply supported lattice trusses of 116ft span at one end and one such truss at the other, together with two simply supported plate girders of 54ft span at each end. All the main girders are of St.44 constructional steel. The Kemi river bridge was designed by Professor Hannelius for the Finnish State Railways. The builders were The Cleveland Bridge and Engineering Company, Ltd., of Darlington.

The second new structure, the Jännevirta Bridge, situated near the town of Kuopio, is a steel highway bridge with a Langer truss of 328ft span over the main opening. The side openings consist of various plate girder spans and a swing bridge at one side, and at the other side a continuous girder extending over two openings each of 67ft. The roadway width amounts to 21ft; the decking slab is of reinforced concrete. The Langer truss span was completely assembled on the bridge approach with two openings, raised to a suitable height above water level by a pontoon, and finally lowered on to its piers. The bridge was designed by B. Kivisalo for the Finnish Highway Board. The structure was erected by Voest, of Linz, Austria.

Industrial and Labour Notes

British Productivity Council Conference

Last week members of the British Productivity Council held a conference with the chairmen or representatives of forty local productivity committees which have been formed recently or are in course of formation. The object of the local productivity committees is to bring together individuals from all levels of industry interested in higher productivity and promoting the prosperity of local industry, and to facilitate the exchange of experience between firms and individuals. Spokesmen of the council emphasised that since conditions varied in each area the committees would want to act very largely on their own initiative and draw upon their local knowledge in formulating their plans. The council would, however, be able to give the committees considerable assistance by supplying lecturers, providing notes or reports, arranging the loan of films, &c., and assisting financially. An encouraging report was given on the progress which had been made in the formation of local productivity committees and a number of suggestions as to the type of programmes that might be undertaken were put forward both by the council and the chairmen of the committees themselves. These suggestions will be examined in detail by each committee in respect of the conditions prevailing in its area. The report on the meeting states that it is hoped by the end of October committees will be functioning in practically all of the 100 areas originally envisaged.

Mr. Tom Williamson, the general secretary of the National Union of General and Municipal Workers and a member of the British Productivity Council, presided over the meeting. In the course of his address to the meeting Mr. Williamson said that the policy of the council was to decentralise its campaign through the medium of the local committees, and there was a large source of local experience and goodwill which had not yet been fully mobilised. He said that we must face the fact and recognise that the fear of redundancy had, to some extent, militated against the acceptance by workers of improved methods of production, and it was for employers and trade unions to remove those fears. There was plenty of evidence to show that by co-operation between management and workers the question of redundancy could be satisfactorily resolved. The fear of redundancy was a real one and was capable of being exploited, but the local committees could do much to remove it. The real threat of large-scale redundancy would come from failure to sell in the markets of the world and the only remedy was to keep the price and quality of our goods on a competitive basis by efficient methods of production.

Electricity Supply in the Coming Winter

The report of the Electricity Sub-Committee of the Joint Consultative Committee for 1953 has just been published It states that there should be sufficient generating capacity available to render unnecessary disconnection of electricity supplies in average cold spells during the coming winter, although voltage reduction will still be necessary. In the event of extremely cold weather some 400MW would have to be shed by disconnection of supplies. The estimates are based on overall national conditions and the report points out that the demand and supply position varies considerably between different areas. The position is least favourable in the Glasgow, Birmingham and Bristol grid control areas, where it is estimated that after full use has been made of the available transmission capacity and voltages have been reduced, deficits of 2 to 3 per cent will remain at the winter peak in average cold spell weather. For this reason disconnection of supplies will be necessary in these three areas unless special arrangements are made for reducing demand.

After taking all the facts into consideration the sub-committee recommends that no formal national load spreading target should be set for the coming winter months. Instead, Regional Boards should have discretion to make load spreading arrangements in the light of the conditions likely to arise in their respective areas. It is further recommended that the load spreading committees should remain in being and that all possible encouragement should continue to be given to the use of private generating plant during winter peak hours.

A Study of New Coking Processes

A communication received from the Organisation for European Economic Co-operation points out that the shortage of coking coal makes the development of coking processes for non-coking coals of considerable importance to European countries. The study of such processes has received relatively little attention so far, as industrial trials of this type of process call for costly installations. The general interest of these problems and the considerable resources required to solve them led the O.E.E.C. to set up a special working party to study them. This working party has drawn up a list of the carbonisation and semi-carbonisation processes other than the standard coke oven method. The list includes current processes, new processes which have reached the industrial stage and new processes not yet tried out industrially.

The information collected enabled the working party to select from the latter group three processes tried out in Germany and in Norway or still under study in the United States, which seem likely to prove applicable to a wide range of different types of coal. The creation of international working parties to study these processes is now under consideration.

A summary report of these processes is available to the public and may be obtained, on request, from the Secretariat of the Productivity and Applied Research Committee, O.E.E.C., 2, Rue André-Pascal, Paris, XVI.

Private Trading in Copper

Last week the Ministry of Materials announced that following discussions with representatives of consumers, producers and the London Metal Exchange, arrangements have been made to supply copper to the markets in this country during the transitional period of a few months after the resumption of private trading in that metal. Copper purchased up to August 4th will be imported during the interim period by the Ministry and in order to fill the gap that will occur between August 5th and the time at which supplies through trade channels can reach this country in sufficient quantities there will be releases from the Government's trading stocks. The amount to be released, at present estimated at about 60,000 tons, will be available for sale through normal commercial channels. The prices at which these sales (apart from sales direct to consignment stockholders) will be made will be based on the average market price over an extended period of months. The releases represent no addition to the metal which would in any case be delivered in the United Kingdom to meet the requirements of consumers.

Ministry sales of copper will be handled by a Government broker who, it is intended, will be a seller only when the needs of the market cannot be met from other sources—otherwise consumers will be expected to secure their supplies through normal commercial channels.

European Steel Production

The quarterly bulletin of steel statistics issued by the United Nations Economic Commission for Europe indicates that although steel production in the United Kingdom continued to increase, it was relatively stable in other countries except Western Germany, where during April and May output dropped. This drop in production in Western Germany followed the record high level reached in the first quarter of the year, although a reduction in steel imports is considered to indicate that output will resume its previous high level.

The trading figures of the other main European steel importing and exporting countries have recently tended to become stabilised, according to the bulletin. It shows that exports are at a lower level than in 1951 owing to the falling-off of overseas demands. In the United Kingdom the continuing rise in home production of steel was accompanied by a trend for imports to drop back towards a normal level.

The trend towards a more rational utilisation of scrap through feeding it into steel furnaces rather than blast-furnaces, which, the report says, could be observed throughout 1952, was maintained in the first quarter of 1953 in Europe as a whole. The trade figures in raw materials for the period under review when compared with the corresponding quarter in 1952 show that the United Kingdom imports at 184,000 tons increased by well over half.

It is stated in the report that steel production in the United Kingdom during the first quarter of 1952 was at an equivalent rate of 16,200,000 metric tons annually, and it reached 18,500,000 metric tons during the second quarter of 1953. In the first quarter of 1953 the equivalent annual production in Western Germany was 17,100,000 metric tons, but it dropped to 13,900,000 metric tons in the second quarter. Estimates showed that the annual rate of steel production of the U.S.S.R. was 34,500,000 metric tons and its associated countries 10,700,000 metric tons.

Tungsten Ores Price Reduction

It has been announced by the Ministry of Materials that the selling prices for standard tungsten ores of standard 65 per cent grade and ordinary quality have been reduced. The new prices are based on the current London market prices, and wolframite will be reduced from 335s. to 327s. 6d. and scheelite from 325s. to 312s. 6d. per long ton unit delivered to the consumers' works.

Engineers' Wages

At a Press conference in Cardiff recently Mr. H. A. Smith, the president of the Engineering and Allied Employers South Wales Association, said that employers in the engineering industry would be hard to convince that a wage increase would be justified. He pointed out that the wage rates quoted by the unions in negotiations were minimum time rates that excluded piece-work earnings, in lieu of bonuses and overtime. The unions, said Mr. Smith, saw that the only hope of obtaining an increase lay in their quoting wage rates that were applicable to only a proportion of the workers, and that they were not willing to assist the lower paid workers other than through an all-round increase. He contended that, as a majority of engineering employees were in receipt of piecework incentive or other bonus schemes, an increase in both production and wages could be obtained without detriment to selling possibilities in the export market if restrictive practices were dropped in the shops.

Wage Restraint and the T.U.C.

The preliminary agenda for the Trades Union Congress to be held in September has been issued. Four unions have put forward resolutions opposing any form of wage restraint. One of these unions, the National Union of Public Employees, will ask the T.U.C. general council to examine and report upon the possibility of a long-term wage policy, with particular reference to whether some form of national regulation and/or control of wages can be devised which will ensure higher, more stable, and more equitable wage standards to all sections of the movement, and to advise upon the changes, if any, which may be necessary in the practice and organisation of the trade unions in order to give effect to such policy.

Notes and Memoranda

Air and Water

LINER CONVERSION.—The Orient Line has announced that the "Orontes," at present carrying first and tourist-class passengers, will be converted to a one-class ship and will in future carry only tourist-class passengers. The public rooms and games decks will remain unaltered, but the conversion will increase the passenger capacity by approximately 250.

HIGH-SPEED OIL TANKERS.—It was announced by Sir William Fraser, the chairman of the Anglo Iranian Oil Company, Ltd., at the launch of the "British Merchant" that two of the 32,000 tons deadweight tankers in the current building programme will have an operational speed of 18 knots. One ship will be built by Swan, Hunter and Wigham Richardson, Ltd., and the other by R. and W. Hawthorn Leslie and Co., Ltd.

OVERHAUL LIFE OF "GHOST" JET TURBINES.—As a result of the experience gained during the first thirteen months of the B.O.A.C. "Comet" services, the "Ghost" engines operated by both the Corporation and the French company, Union Aeromaritime de Transport, have now been officially cleared to operate for 600 hours between overhauls. At "Comet" cruising speeds this period is equivalent to flying ten times round the world. A batch of B.O.A.C. engines has now commenced running a trial extension to 750 hours. At the end of June, 1953, "Ghost" engines in service had completed over 60,000 hours and at present they are flying nearly 5000 hours each month—equivalent to an aircraft utilisation of more than 2000 hours per year. The average B.O.A.C. "Ghost" engine now attains over 85 per cent of its approved life. B.O.A.C. "Ghost" engines are being overhauled by the de Havilland Engine Company at an average rate of sixteen engines a month, many of them for the third time. Union Aeromaritime de Transport is achieving about 1700 engine hours each month, or more than 5000 hours a year. Its experience indicates that the maintenance man-hours per flying hour for the "Ghost" are only about half those required for the piston engines which it also employs.

Miscellanea

CONSTITUTION OF I.E.E. COUNCIL, 1953/54.—Commander (L) C. V. Robinson, O.B.E., R.N., has been elected chairman of the Southern Centre of the Institution of Electrical Engineers for 1953/54, in place of Mr. C. W. A. Priest, B.Sc. (Eng.), who has tendered his resignation.

HANDLING CONCRETE ON HOUSING SITES.—The latest of the Ministry of Works' advisory leaflets (No. 32) has the above title and is devoted to an explanation of some of the practical points which must be observed to get the best output from small concrete mixers and concreting gangs at work on housing sites.

DEFENCE PRODUCTION.—In a written Parliamentary answer, the Minister of Supply, Mr. Duncan Sandys, has stated that at present about 87 per cent of the capacity of the engineering industry is engaged in civilian production. It is not anticipated that the cessation of hostilities in Korea would have any appreciable effect on defence production.

OIL PRODUCTION IN IRAQ AND KUWAIT.—For the first six months of this year the total Iraqi production from the Kirkuk, Zubair and Ain Zalah oil fields was 13,119,806 tons, which compares with the 7,001,802 tons produced during the corresponding period in 1952. At Kuwait the corresponding crude oil production totals were 20,589,588 tons and 18,255,018 tons, respectively.

PLASTIC SHEETING BROCHURE.—We have received a booklet from Bakelite, Ltd., 12–18, Grosvenor Gardens, London, S.W.1, concerning its "Vybak" rigid sheets. This sheet material is made from vinyl chloride-acetate and polyvinyl chloride resins and details concerning its manufacture and physical properties are given, together with information on machining, forming, cementing and finishing the material.

INDUSTRIAL PROTECTIVE GLOVES.—A new industrial glove, introduced by James North and Sons, Ltd., of Hyde, Cheshire, has the palm and front of the fingers coated with P.V.C., and the fabric back left uncoated. This design improves the ventilation, making the glove cool to wear over long working periods. The gloves are made either with a smooth finish to the palm for light work or with a heavier roughly finished palm for heavy duty.

ELECTRONIC EXPERIMENTAL STATIONS.—Replying to a question in Parliament, the Minister of Supply stated that the Ministry's two electronic experimental stations at Malvern are to be amalgamated under the directorship of Mr. W. J. Richards, who has been Chief Superintendent of the Telecommunications Research Establishment since 1946. Hitherto one of the stations at Malvern was primarily engaged on radar research for the Army, whilst the other was concerned with the Air Force and Fleet Air Arm.

POPLAR TECHNICAL COLLEGE.—The new extension to Poplar Technical College was opened recently by Mr. R. McKinnon Wood, chairman of the L.C.C. Education Committee. Accommodation has been provided in the new building for a heat treatment laboratory, a foundry, a motor vehicle shop, electric and gas welding, together with an elementary engineering science laboratory, lecture rooms, drawing offices and an electrical installation room. A flour milling demonstration room—the only one south of Liverpool—is being equipped by the flour milling industry.

301kV SINGLE-PHASE GENERATOR TRANSFORMER FOR KEMANO, BRITISH COLUMBIA.—The first of four 71,000 kVA, 301kV, single-phase, Ferranti generator transformers for the "Alcan" project of the Aluminum Company of Canada, Ltd., Kemano, British Columbia Canada, left the Ferranti factory at Hollinwood, on August 4th. These transformers are the first power units to be ordered and manufactured in this country for a working voltage in excess of 300kV. The transformers will be installed underground some 300ft below ground, 400 miles north of Vancouver, see (THE ENGINEER, May 29 and June 5, 1953).

BRITISH STANDARDS INSTITUTION.—The transfer of the British Standards Institution to its new premises, No. 2, Park Street, W.1 (telephone Mayfair 9000) will be completed on Monday, August 17th. The work of removal will extend over the whole of the preceding week and during this period services to Institution members and committee members will be fully maintained. The new building will contribute to more efficient working by concentrating the B.S.I.'s scattered departments under one roof. It will also provide increased and more convenient accommodation for the 1300 specialists who attend the 3500 committee meetings held during the course of each year.

TIN RESEARCH.—In the twenty-eighth Bulletin, "Tin and its Uses," issued by the Tin Research Institute, mention is made of a new aluminium-tin bearing alloy. It is suggested that it may soon be practicable to substitute instead of copper-lead bearings a new alloy of aluminium with 30 per cent of tin. The advantages of the new alloy are that it can be used in contact with mild steel shafts that have not been specially hardened, its anti-friction properties are excellent and it is relatively cheap; it can be bonded to steel strip or to duralumin backings. The bulletin refers also to a copper-nickel-tin coining alloy. Modern "silver" coins generally contain upwards of 25 per cent of nickel. A new alloy containing only 15 per cent of nickel and 5 per cent of tin which has been produced experimentally at the Tin Research Institute compares well in brightness and has the other qualities of toughness and durability needed in coins.

A MINE DRILL DUST EXTRACTOR.—Some notes have been issued by the National Coal Board of the Allison dust extractor, which has been designed for use with electric drills underground to provide a dry dust trap as efficient as those used with compressed air drills. Based on the principle of the household vacuum cleaner, the extractor consists of a rubber seal, which slips over the drill rod and fits round the mouth of the hole, a rubber connecting hose and a filter box. A fan to provide the air flow from hole to filter box is fitted below the box and driven by a drilling machine motor. Tests with the machine have been made with an ordinary 1·25 h.p., 125V drill, and a similar motor, without gears, has been fitted to the extractor fan to enable both the drill and the extractor to be run from one double-circuit panel. In tests the extractor collected from a 12in hole drilled in post stone 32 grammes of very fine dust and 976 grammes of coarse dust. The designer of this extractor is Mr. J. Allison, "E" Group Electrical Engineer of No. 2 Area, Durham Division.

SEVENTH ELECTRONICS COURSE AT HARWELL.—The Atomic Energy Research Establishment at Harwell is to hold its seventh specialised course on the design, use and maintenance of electronic instruments used in nuclear physics, radio-chemistry and work with radio-isotopes. It will take place at the Isotope School, from Monday, September 28, to Friday, October 2, 1953, and will include lectures and practical work concerned with counters, d.c. and pulse amplifiers, coincidence units, scalers and rate-meters, all the subjects being in the "unclassified" category; the lecturers and demonstrators will be specialists from the Atomic Energy Research Establishment. The fee for the course is twelve guineas and living accommodation, transport and morning and evening meals will be provided at a charge of seven guineas. The course is limited to twelve participants and applications are invited from physicists or electronic engineers with degrees or equivalent qualifications. Application forms can be obtained from the Electronics Division, A.E.R.E., Harwell, near Didcot, Berks, and they must be returned by Friday, September 11, 1953.

POSTGRADUATE COURSE IN PUBLIC HEALTH ENGINEERING.—The third postgraduate course in public health engineering organised by the Imperial College of Science and Technology and the London School of Hygiene and Tropical Medicine was completed this year, the first session since the termination, in September, 1952, of the period during which grants were received from the Rockefeller Foundation towards the establishment of the course. The course is now financed entirely from university funds and has been accepted as part of the postgraduate curriculum of the university. The objectives of the course have remained unchanged, namely, to provide a sound understanding of the sciences, both physical and biological, on which public health engineering work is based, and an appreciation of the general public health background to that work, together with instruction in the techniques used in the major branches. While the supply and treatment of water and the removal of wastes, including sewage and refuse, continue to claim the greater part of the time devoted to these techniques, considerable attention is also paid to problems of air hygiene, occupational health and tropical hygiene. The latter subject is being developed for the benefit of students from the Colonies and other overseas countries. It is intended that in future courses these students shall be able to specialise to an increasing extent in the study of the types of problem peculiar to the areas in which they work.

TECHNICAL POSTS IN COAL MINING.—An illustrated booklet, entitled *Coal Mining: Managerial and Technical Posts*, has been published in the "Choice of Careers" series issued by the Central Youth Employment Executive. It describes the work of responsible mining officials and the abilities, qualities and training required. Details are given of the day-to-day duties of the manager, under-manager, overmen and deputies, and surveyors, as well as some information about salaries and openings, both in this country and abroad. About 200 technicians and officials including managers, under-managers and surveyors, together with about 1000 deputies and overmen, have to be found each year by the National Coal Board to meet the requirements of the collieries. The booklet gives a description of the National Coal Board's scheme of "Directed Practical Training" for those who aim at posts as managers, or as mechanical or electrical engineers. The Board plans to recruit up to 200 trainees each year under the scheme, which is open to men holding degrees in mining, mechanical, electrical or chemical engineering and to young men in the industry who have obtained a recognised mining or engineering qualification and who possess the personal qualities required for responsible positions. Scholarships are available for boys who have done well at school and for those within the industry who have reached the educational standard necessary for admission to a university. The price of the booklet is one shilling. It can be obtained from H.M. Stationery Office.

Personal and Business

MR. S. A. ROBERTS, of Moor Hall Park, Sutton Coldfield, has been appointed general manager of the B.S.A. Tools Group of Companies.

HENRY MEADOWS, Ltd., announces that Mr. A. D. Mackay, the managing director of the Bergins Company, Ltd., Glasgow, has been appointed deputy chairman to the board.

SIR CYRIL BIRTCHNELL, K.C.M.G., C.B., Deputy Secretary to the Ministry of Transport, is retiring from the public service in September and Mr. Philip Dennis Proctor, C.B., has been appointed to succeed him.

MONKS AND CRANE, Ltd., of Birmingham, has opened a branch office in Glasgow at 79, Crown Street, C.5 (telephone: South 2907). Mr. A. McCabe has been appointed to Scottish Area Manager by the firm.

DEWRANCE AND CO., Ltd., announces that its Birmingham office has been transferred to 62, Exchange Buildings, Stephenson Place, Birmingham, 2 (telephone number Midland 4621, as from July 20, 1953). Mr. A. Brown is the company's manager for this area.

MR. C. C. BATES, M.I.W., A.M.I.P.E., has been appointed chief welding engineer of Costain-John Brown, Ltd., South Audley Street, W.1. In addition Mr. Bates will be responsible for the technical supervision of Welding Supervision, Ltd., an associate company.

MR. R. F. RICHARDSON, M.B.E., A.M.I.E.E., a member of the commercial manager's staff of the British Electricity Authority, has been appointed an assistant commercial manager of the Authority. He succeeds Mr. F. S. Naylor, B.Sc. (Eng.), M.I.E.E., A.C.G.I., whose appointment as specifications and contracts engineer was announced recently.

TURNER AND NEWALL, Ltd., announces that it has acquired a controlling interest in a Brazilian brake lining company, Industria Nacional de Lonas Para Freio S.A., on behalf of one of its subsidiaries, Ferodo, Ltd., Chapel-en-le-Frith, England. The product of the Brazilian factory, which is situated at Sao Roque in the State of Sao Paulo, is at present known by the trade name "Brakewell," but it is intended that in due course "Ferodo" clutch and brake linings will be made and marketed.

MR. H. W. GRIMMITT, M.I.E.E., A.M.I.Mech.E., at present Deputy Chief Engineering Inspector in the Electricity Division of the Ministry of Fuel and Power, has been promoted to be Chief Engineering Inspector, with effect from September 1st, in succession to Mr. A. N. East, C.B.E., M.I.E.E., M.I.Mech.E., Assoc.I.C.E., who retires on that date. Mr. Grimmitt was appointed to his present post on the winding up of the Electricity Commissioners in September, 1948. He had served with the Commissioners since 1930.

THE directors of Wickman, Ltd., of Coventry, announce that Mr. H. Eckersley, M.I.Mech.E., M.I.P.E., general manager of the Wimet Division, and Mr. W. V. Hodgson, M.I.P.E., general manager of the Machine Tool Division, were appointed to the board of the company on July 15, 1953. With the increase in the company's activities, the directors decided to establish a local board and have appointed as special directors Mr. R. J. Dixon, chief engineer; Mr. T. W. Hayes, export sales manager; and Mr. S. W. Perkins, machine tool sales manager.

THE directors of The North British Rubber Company, Ltd., Edinburgh, and the Dominion Rubber Company, Ltd., London, announce that the sales and branch service organisations of the two companies will be consolidated. The North British Rubber Company will undertake the distribution in the United Kingdom of all products—tyres, footwear and general mechanical goods—previously handled by the separate sales divisions of the two companies. The Dominion Rubber Company will undertake the distribution of North British and Dominion products overseas. The products of both the companies will be manufactured at Castle Mills, Edinburgh, and Heathhall, Dumfries.

British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

HEAT EXCHANGERS

693,476. October 22, 1951.—HEAT EXCHANGERS, Aktiebolaget Separator, 8, Fleminggatan, Stockholm, Sweden.

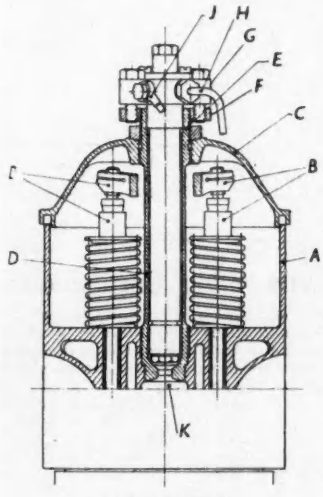
The invention relates to heat exchangers of the plate type. The drawing shows one arrangement of the invention. The plates *A*, *B* and *C* form together two flow spaces for the heat-exchanging fluids. On either side of the plates there are other identical plates, forming together a set of plates in the heat exchange. The two fluids flow in the spaces in the directions indicated by the arrows. The plate *A* is corrugated to form steps, one side *D* of which, in section, is about twice as long as the other side *E*. Consequently, the section of the corrugated plate forms a zig-zag line with the sides of the steps at nearly right-angles to one another. The corrugations of the plate *C* are identical with those of the plate *A*, whereas the plate *B* is similarly corrugated but with the corrugations displaced vertically in relation to those of the plates *A* and *C* and having the long sides *D* and short sides *E* sloping in opposite directions as compared with the adjacent plates. Thus, flow spaces of triangular cross-section, when viewed in a direction parallel to the corrugations, are formed between adjacent plates, the spaces communicating with one another through passages, each of which is defined on one side by a flat wall and on the other side by a wall including a corrugation ridge. In the drawing straight corrugation lines between the steps are shown. It is, however, sometimes advisable to form bosses or small corrugations in the material of the plates at or close to the corrugation lines, because the turbulence is then further augmented.—*July* 1, 1953.

No. 693,476

INTERNAL COMBUSTION ENGINES

693,148. May 15, 1951.—FUEL-INJECTION IN INTERNAL COMBUSTION ENGINES, Societe d'Etudes de Machines Thermiques, 24–26, rue de la Gare, La Courneuve (Seine), France.

An object of the invention is to provide a fuel injection system in which all danger of the fuel contacting the lubricating oil in case of a leak is eliminated, and in which the various component parts are easy of access. In the drawing, the sealed cylindrical casing *A* contains the usual valve-operating rocker mechanism *B* for the cylinder inlet and exhaust valves, and is sealed by a top cover *C*. A tubular member *D* extends coaxially through the casing, being sealed with the casing at its bottom and with the cover *C* towards its top. It projects upwards beyond the casing cover as at *E* and has at its upper end a member *F* which supports a fuel supply chamber *G* having pipe connections *H* and *J*. The tubular member *D* at its lower end supports a fuel injector *K*. It will be seen that in the operation of the engine the fuel will flow from the intake connections *H* and *J* down through the tubular member *D* to the injector *K* without any possibility of its being mixed with the oil in the casing.—*June* 24, 1953.

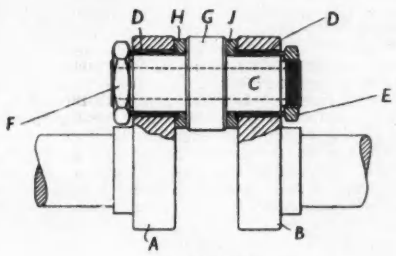


No. 693,148

BEARINGS AND SUPPORTS

693,530. April 25, 1951.—METHODS OF SECURING A PIN IN A MEMBER, Ringfeder G.m.b.H., Duisburger Strasse, 145, Krefeld-Uerdingen, Germany

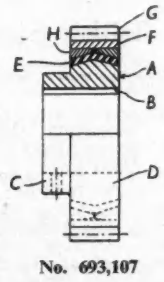
Referring to the drawing, the crank webs *A* and *B* are connected by a pin *C*. They each have a bore larger than the diameter of the pin, so that a ring spring *D* can be introduced into the bores. Each ring spring is formed from a number of closed inner and outer rings. Nuts *E* and *F* are secured one on each end of the pin. The pin has a central collar *G* and abutment members *H* and *J* are provided one on either side of the collar. The nuts are tightened to clamp the ring springs against the abutment members and entirely fill the annular space between the pin and the bore. On further tightening of the nuts, since no further expansion of the rings of the springs can occur, the pin is wedged in the bores to such an extent that normal operating torque on one shaft can be transmitted to the other shaft without slip taking place between the pin and either of the webs. The individual parts of a crankshaft so constructed can be produced as simple forged articles and can be worked on normal machine tools. The ring springs employed and all other accessories can be simply and cheaply produced with high precision. If the clamping pressure is suitably chosen a safety device against overloading is obtained since in the event of overloading the adhesive friction is overcome and slip takes place.—*July* 1, 1953.



No. 693,530

693,107. January 19, 1950.—FLEXIBLE UNITS, Dunlop Rubber Company, Ltd., 1, Albany Street, London, N.W.1. (*Inventors: Harold Wilson and Paul Brierley.*)

The invention provides flexible units, particularly torque transmission flexible units and resilient mountings, comprising a rubber sleeve compressed between rigid members, which are of simple construction and the assembly and repair are facilitated by the manner of retention of the rubber sleeve. As shown in the drawing, the resilient gear-wheel comprises an inner member *A* having a key-way *B* formed in the bore for securing the inner member to a shaft. There is a boss *C* on one face and the outer periphery of the body is conically tapered on each side. A cylindrical rubber bush *E* having in its unstressed condition an internal diameter somewhat less than the smaller diameter of the outer periphery of the body portion *D*, is stretched and fitted on to the body. An outer annular member *F* having gear teeth *G* on its outer circumference, is located coaxially around the body and rubber bush and secured in place by metal annular retaining elements *H*, which are forced into the bore of the outer member *F* from opposite sides. Each retaining element is of triangular cross-section, and in the unstressed condition the outside diameter of the elements is slightly more than the diameter of the bore of the outer member *F*. In the assembled gear-wheel there is thus interference at the interface between the outer member and the retaining elements and the necessary forcing in of the elements is facilitated by providing a slight lead on the entrance side of each element. Should it be required to take the resilient gear-wheel apart, this may be done simply by pressing out the retaining elements, rubber bush and inner member from the outer member. Both retaining elements are pushed out from the outer member on the same side although inserted from opposite sides on assembly. A resilient gear-wheel of this kind has the advantage that it is necessary to replace only the outer member if the teeth become badly worn or broken. Similarly, either the inner member or the rubber bush can be replaced if necessary without changing other components of the assembly. In the specification flexible units for rail-wheels, gear-wheels and base supports are also shown.—*June* 24, 1953.

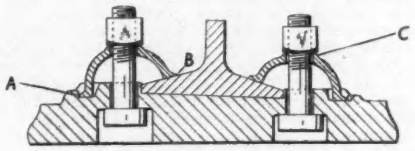


No. 693,107

RAILWAY ENGINEERING

693,585. November 3, 1950.—SPRING CLIPS FOR SECURING RAILWAY TRACK, Toledo Woodhead Springs, Ltd., Clifton Works, Neepsend Lane, Sheffield. (*Inventor: Guy Leslie Murray.*)

The invention relates to spring clips for securing railway track, comprising flat section material formed into an arch. The ends of the arch are caused to press on the bottom flange of the rail and the supporting soleplate or sleeper, respectively, by means of a nut screwed on to a threaded stem extending upwards from the soleplate and passing through a hole in the upper part of the arch. In the drawing there is shown a spring clip in operative position. It is of generally uniform flat section, arching upwards from the two feet *A* and *B*, which contact with the rail flange and the soleplate. Each foot is turned outwards to form a toe projecting from the body. The foot thickens from the toe towards the body, which it joins by a smooth curve. The crown of the arch is pierced with a clearance hole for the bolt projecting from the soleplate. In the drawing the arch is shown thickened at *C* to reduce the risk of fracture because of any weakening resulting from the hole, but if the strength of the section permits a uniform thickness may be maintained across the crown. In the specification modified designs of clips are shown and their manufacture described. *July* 1, 1953.

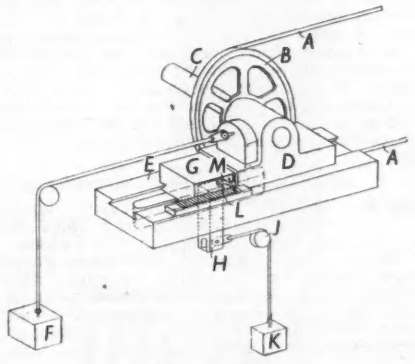


No. 693,585

POWER TRANSMISSION

693,366. June 16, 1950.—CONVEYOR CHAIN TENSIONING MECHANISM, Melvin and Gillespie, Ltd., 28, Charles Street, Glasgow, and William Angus Hall, "Holmside," 26, Kells Lane, North Low Fell, Gateshead.

The invention relates to means for automatically controlling the tension of endless conveyor chains or belts by means of balance weights. As shown in the drawing, an endless belt *A* is trained over wheels, one of which is a driver rotatable about a fixed axis, and another, *B*, is mounted on a shaft *C* mounted in a bearing block *D* on a stool *E* so as to be movable in a direction parallel to the length of the belt. Attached to the movable bearing block *E* by a rope or cable is a main heavy balance weight *F* sufficient to exert a pull adequate to overcome any possible accidental obstruction in the belt circuit. On the stool *E* is mounted a slidable block *G* from which hangs a bracket *H* from which extends rearwards part of a belt trained over a stationary pulley *J* and having at its lower end a counter-balance weight *K* of less mass than the main balance weight *F*. The counterweight *K* urges the bearing block *D* in the opposite direction to the pull exerted by the main weight *F* so that the resultant pull on the belt exerted by the main weight is reduced by the amount of this counter-balance weight *K*. This weight may be varied so that the desired minimum pull to tighten the belt is obtained. The movable stenting wheel *B* moves forward with elongation of the belt caused

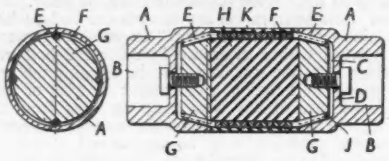


No. 693,366

by expansion by heat or by wear. In this forward movement of the stenting wheel the two blocks *D* and *G* travel forward in unison, whilst continuing to oppose one another. If an accidental obstruction should occur in the belt circuit, the stenting wheel *B* will be pulled back, but the block *G* is arrested in its backward movement and the counter pull influence is interrupted, so that the pull exerted by the main weight *F* will be effective to overcome the obstruction. This arrest of the block *G* is obtained by providing a stationary ratchet bar *L* on the stool *E* and a pawl *M* on the block *G*. The pawl slides over the teeth of the ratchet on the expansion of the belt but immediately the stenting wheel is subject to the influence of the obstruction the pawl arrests backward movement of the block *G* so that the weight *K* is non-effective. The arrangement is particularly applicable to a travelling oven, but the invention is not limited to that use.—*July* 1, 1953.

693,844. October 5, 1950.—POWER-TRANSMISSION COUPLING, The Dunlop Rubber Company, Ltd., 1, Albany Street, London, W.1. (*Inventors: Paul Brierley and Geoffrey William Trobridge.*)

An object of the invention is to provide a universal coupling which is simple in construction and which has no relatively rotatable bearing surfaces. The coupling shown in the drawings comprises a pair of coupling members *A*, one at each end. Each member is bored out to provide a recess *B* for accommodating the end of a shaft to be coupled. The other end is bored out so as to form a frusto-conical cavity *C* which tapers inwards from the end of the member. A thin wall of metal *D* separates the recess from the cavity. Substantially axially extending ends *E* of a multiple helical spring unit *F* which extends between the members *A* are clamped against the walls of the cavities by clamps *G*. The bore of the spring unit *F*



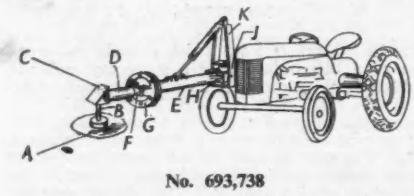
No. 693,844

is filled by a solid cylindrical soft rubber core *H*. The multiple helical spring unit which constitutes the flexible power transmitting portion of the coupling is made up of four separate springs. Adjacent coils of the springs are contiguous and the outside diameter of the spring unit is the same as the major inside diameter of the cavities *C*. Each clamp *G* is provided with a co-axial tapped hole in its outer end face for engaging a clamping screw, as shown. The major and minor diameters of the clamp are both smaller than the corresponding diameters of the cavity. The conical surface of the clamp is provided with four equally spaced, axially-extending grooves *J*), the depth of each groove being less than the diameter of the spring wire) and co-operates with the surface of the corresponding coupling member. The solid cylindrical preformed core *H* of soft vulcanised rubber has an outside diameter substantially the same as the inside diameter of the spring coils and is inserted co-axially with the spring unit, the length of the core being such that each face of the cylinder is flush with an end of the spring unit *F*. Thus all the coils of the unit are in contact with the core. A rubber sleeve *K* fits over the outside of the coils to protect them. The direction of rotation of the coupling is such that the spring coils tend to tighten up on to the rubber core. Under these circumstances, the core prevents any undesirable deformation of the spring unit and any substantial decrease in the diameter of the spring coils.—*July* 8, 1953.

AGRICULTURAL ENGINEERING

693,738. December 19, 1951.—TRACTOR-BORNE CUTTING TOOLS, Jack Foster, and J. Foster and Co., Ltd., North Cave, Brough, East Yorkshire.

The invention relates to tractor-borne power driven cutting tools for hedge trimming, scrub-clearing, tree felling, logging and similar operations which may be performed by a rotary saw or similar rotary cutting tool. Referring to the drawing, a rotary cutter *A* comprising a circular saw blade



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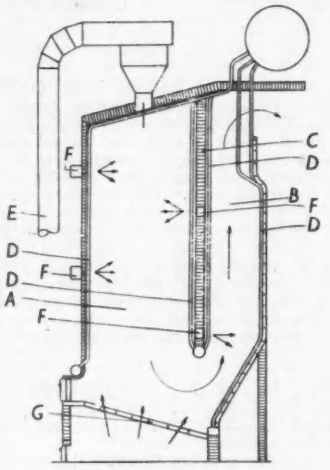
is detachably mounted on the end of a shaft *B* which is driven by means of bevel gears in a casing *C* carried at the end of a member *D* by a shaft which is supported in anti-friction bearings and is connected through a universal joint to a shaft in a tubular boom *E*. The member *D* is made fast at its end remote from the casing *C* to a member *F* by means of which it is pivoted to the projecting lugs of an annular part *G* on the end of the boom. The opposite end of the boom carries a bifurcated member *H*, the limbs of which pivot about a horizontal axis on journals carried by a frame mounting *J*. This mounting is extended as at *K* to form a pivotal support for the body of a jack, the ram of which is connected to the boom. The drawing shows the general arrangement of the tractor and the cutting tool.—*July* 8, 1953.

FURNACES

693,718. January 30, 1951.—FIRING DEVICE FOR LOW CALORIFIC VALUE SMALL FUELS, Vereinigte Kesselwerke Aktiengesellschaft, Werdenerstr, 3, Düsseldorf, Germany.

The invention relates to the combustion of fuels of low calorific value and small particle size having a high water and ash content, such as peat and provides means by which such fuels can be efficiently burnt by a boiler. In the construction shown the firebox is divided into two combustion chambers *A* and *B* by a guide wall *C* projecting downwards from the top. It may be lined completely or partly with cooling conduits *D*. The fuel is fed through pipe *E* from a pulveriser and passes through a screen and drops from above into the chamber *A*; in passing through the chamber, the fuel is mixed with the necessary combustion air from air boxes *F*. At the bottom of the two combustion chambers is a grate *G* through which a forced draught may be impelled upwards from an undergrate chamber.



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The arrangement is such that the heavy fuel particles drop on the grate where they can be burnt out completely, whilst the lighter particles rise into chamber *B* and are burnt with a further air supply and finally are admitted to the heating surfaces of a boiler. A modified construction with three combustion chambers is also shown in the specification.—*July* 8, 1953.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 24, Victoria Street, London, S.W.1.

SWAGED CABLE-END ASSEMBLIES FOR PREFORMED STEEL WIRE AND NON-CORRODIBLE STEEL WIRE ROPE FOR AIRCRAFT

No. SP.53–SP.54 : 1953. These two publications cover the fittings, requirements and coding for aircraft swaged cable-end assemblies on preformed steel wire rope complying with British Standards W.9 and W.11. The fittings comprising the assemblies and turnbarrels and tension rods for use with them are those covered by British Standards already included in the aircraft series, namely British Standards SP.33 to 39 and SP.49 to 52. Requirements for the locking of the assemblies are not covered by these specifications. Price SP.53, 6s.; SP.54, 3s.

Launches and Trial Trips

BRITISH MERCHANT, oil tanker; built by Swan, Hunter and Wigham Richardson, Ltd., for the British Tanker Company, Ltd.; length between perpendiculars 630ft, breadth moulded 85ft 6in. depth moulded 46ft 6in, deadweight 32,000 tons on 35ft draught, loaded service speed 14½ knots, thirty cargo oil tanks, one pump room, three 850 tons per hour turbo-driven cargo oil pumps, three stripping pumps, steam deck machinery; two 600kW turbo-alternators, one 150kW diesel-driven generator, one 50kW steam-driven generator; one set of Wallsend Slipway double reduction geared turbines of 13,750 maximum s.h.p. at 116 r.p.m. of the propeller, taking steam at 450 lb per square inch and 750 deg. Fah. from two Babcock and Wilcox boilers —Launch, July 24th.

NICOLAS, oil tanker; built by the Blythswood Shipbuilding Company, Ltd., for the Parana Companía de Vapores, S.A.; length between perpendiculars 530ft, breadth 72ft 9in., depth moulded 38ft 8in, deadweight 18,600 tons on 30ft 7in draught; nine centre and twelve wing cargo oil tanks; two pump rooms, four 375 tons per hour cargo oil pumps, steam-driven deck machinery, loaded trial speed 15·5 knots; Kincaid-Harland and Wolff-B. and W. two-cycle, single-acting, opposed-piston diesel engine, six cylinders 750mm diameter by 2000mm combined stroke, heavy fuel, 7500 b.h.p.; two single-ended boilers.—Trial, July 28th.

Contracts

THE DE HAVILLAND AIRCRAFT COMPANY, Ltd., has received a further order from Air France for three "Comet" turbo-jet engined airliners. The aircraft will be the Mark II version of the machine.

WESTINGHOUSE BRAKE AND SIGNAL COMPANY, Ltd., has received a contract for the resignalling of Cowlairs (Glasgow), Scottish Region, British Railways, and will be responsible for the supply and installation of the whole of the signalling apparatus. This installation, at present operated from eight mechanical signalboxes, will be replaced by the Westinghouse O.C.S. system from a control desk and diagram in one central signalbox. It will include multi-aspect colour light signals with position light subsidiaries, junction and route indicators, electro-pneumatic points and a.c. track circuits, while remote points will be electrically operated. Plug-in-relays will be used throughout. Standby power plant, together with main and standby compressor plant, is also included. The whole installation covers approximately 14 track-miles and includes work in connection with three adjoining mechanical boxes.

CONTRACTS have been placed by the British Electricity Authority during the past month for power stations, transforming stations and transmission lines amounting in the aggregate to £10,290,453. The principal contracts include: Acton Lane "B" power station, Willesden, two 240,000 lb per hour boilers (Mitchell Engineering, Ltd.); Marchwood power station, near Southampton, structural steelwork (Alex Findlay and Co., Ltd.) and one 550,000 lb per hour boiler (John Thompson Water Tube Boilers, Ltd.); East Yelland power station, near Barnstaple, two 30MW turbo-generators and feed heating plants (C. A. Parsons and Co., Ltd.); Tilbury power station, three 60MW turbo-generators, condensing and feed heating plants (C. A. Parsons and Co., Ltd.) and piling for foundations for second half of station (Holloway Bros., (London) Ltd.); Castle Donington power station, near Derby, 275kV switchgear (British Thomson-Houston Company, Ltd.); Nottingham power station, two 300,000 lb per hour boilers and ancillary equipment (Mitchell Engineering, Ltd.); Wakefield power station, Yorks, high pressure steam feed pipework and valves (Aiton and Co., Ltd.); Stella North power station, near Newcastle upon Tyne, two 60MW turbo-generators, condensing and feed heating plants (C. A. Parsons and Co., Ltd.); Huncoat power station, Accrington, one cooling tower (Film Cooling Towers (1925), Ltd.) and foundations for turbo-generator set and boiler (J. Jarvis and Sons, Ltd.); Barony power station, Ayr, preliminary civil engineering works (John Laing and Sons, Ltd.); Clyde's Mill power station, Glasgow, pipework, valves, steam receivers and tanks (Stewarts and Lloyds, Ltd.); Hartley substation, Kent, 132kV isolators and connections (English Electric Company, Ltd.); Harrow substation, Middlesex, 90MVA, 132/33kV transformers (English Electric Company, Ltd.); Woolwich-Eltham, London, 132kV, 22kV and auxiliary cables (W. T. Glover and Co., Ltd.); Andover, Hants to Thatcham, Berks, 132kV double circuit line (Pirelli-General Cable Works, Ltd.); Lancaster to Quernmore and Blackburn to Quernmore, 132kV overhead line (British Insulated Callender's Construction Company, Ltd.), and Cambuslang to Clyde's Mill, 132kV cables (Pirelli-General Cable Works, Ltd.).

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASLIB

Fri. to Mon., Sept. 11th to 14th.—The University, Nottingham, 28th Annual Conference.

ENGINEERS' GUILD

Thurs., Sept. 24th.—METROPOLITAN BRANCH: Caxton Hall, Caxton Street, Westminster, S.W.1, Annual General Meeting, 6 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Tues., Aug. 18th.—Visit by a Party of Members to the Works of Scammell Lorries, Ltd., Watford, Herts, 10.45 a.m.

ROYAL AERONAUTICAL SOCIETY

Tues. to Fri., Sept. 8th to 18th.—LONDON: Anglo-American Conference.